JC09 Rec'd PCT/PTO 24 OCT 2001

FORM PTO-1390 REV. 5-93 US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEYS DOCKET NUMBER P01,0349 U.S.APPLICATION NO. (if known, see 37 CFR 1.5) 10/009859
INTERNATIONAL APPLICATION NO. PCT/DE00/01276	INTERNATIONAL FILING DATE April 25, 2000	PRIORITY DATE CLAIMED April 28, 1999

TITLE OF INVENTION: "COMPUTED TOMOGRAPHY APPARATUS WITH AUTOMATIC PARAMETER MODIFICATION TO PREVENT IMPERMISSIBLE OPERATING STATES" (AS AMENDED)

APPLICANT(S) FOR DO/EO/US: THOMAS VON DER HAAR

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ■ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. □ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ■ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay.
4. ■ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ■ A copy of International Application as filed (35 U.S.C. 371(c)(2))
   a. ■ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. □ has been transmitted by the International Bureau.
   c. □ is not required, as the application was filed in the United States Receiving Office (RO/US)
6. ■ A translation of the International Application into English (35 U.S.C. 371(c)(2).
7. ■ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3))
   a. □ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. □ have been transmitted by the International Bureau.
   c. ■ have not been made; however, the time limit for making such amendments has NOT expired.
   d. □ have not been made and will not be made.
8. □ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ■ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. □ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ■ An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98; **(PTO 1449, Prior Art, Search Report)**.
12. ■ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. 3.28 and 3.31 is included.
13. ■ A FIRST preliminary amendment.
    □ A SECOND or SUBSEQUENT preliminary amendment.
14. ■ A substitute specification.
15. □ A change of power of attorney and/or address letter.
16. ■ Other items or information:
    a. ■ Submission of Informal Drawings and Request For Approval of Drawing Changes
    b. ■ **EXPRESS MAIL #EJ0776945402US**

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U.S.APPLICATION NO. (if known, see 37 C.F.R. 1.5) 10/009859	INTERNATIONAL APPLICATION NO. **PCT/DE00/01276**	ATTORNEY'S DOCKET NUMBER **P01,0349**

17. ■ The following fees are submitted:

				CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 C.F.R. 1.492(a)(1)-(5): Neither international preliminary examination fee (37 C.F.R. 1.482) nor international search fee (37 C.F.R. 1.445(a)(2) paid to USPTO and International Search Report not prepared by EPO or JPO .... $1040.00 No international preliminary examination fee USPTO (37 C.F.R. 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO .... $890.00 International preliminary examination fee USPTO (37 C.F.R. 1.482) not paid to USPTO but international search fee fee paid to USPTO (37 C.F.R. 1.445(a)(2) .... $740.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) but all claimd did not satisfy provisions of PCT Article 33(1)-(4) .... $710.00 International preliminary examination fee paid to USPTO (37 C.F.R. 1.482) and all claims satisfied provisions of PCT Article 33(2)-(4) $100.00					
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)).				$	
Claims	Number Filed	Number Extra	Rate		
Total Claims	27 - 20 =	7	7 X $ 18.00	$ 126.00	
Independent Claims	1 - 3 =	0	X $ 84.00	$	
Multiple Dependent Claims			$280.00 +	$	
TOTAL OF ABOVE CALCULATIONS =				$1,016.00	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 C.F.R. 1.9, 1.27, 1.28)				$	
SUBTOTAL =				$1,016.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +				$	
TOTAL NATIONAL FEE =				$1,016.00	
Fee for recording the enclosed assignment (37 C.F.R. 1.21(h). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. 3.28, 3.31). $40.00 per property **(see separate envelope)** +				$ (40.00)	
TOTAL FEES ENCLOSED =				$ 1,016.00	
				Amount to be refunded	$
				charged	$

a. ■ A check in the amount of $ 1,016.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ________ in the amount of $ ______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **501519**. A duplicate copy of this sheet is enclosed.

d ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038

NOTE: Where an appropriate time limit under 37 C.F.R. 1.494 or 1.495 has not been met, a petition to revive (37 C.F.R. 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Schiff, Hardin & Waite
CUSTOMER NO. 26574
Patent Department
6600 Sears Tower
233 South Wacker Drive
Chicago, Illinois 60606

Mark Bergner
SIGNATURE

Mark Bergner
NAME

45,877
Registration Number

10/009859
JC13 Rec'd PCT/PTO 24 OCT 2001

BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER THE PATENT COOPERATION TREATY-CHAPTER II

AMENDMENT "A" PRIOR TO ACTION AND SUBMISSION OF SUBSTITUTE SPECIFICATION

APPLICANT:	Thomas von der Haar
ATTORNEY DOCKET NO.	P01,0349
INTERNATIONAL APPLICATION NO:	PCT/DE/00/01276
INTERNATIONAL FILING DATE:	April 25, 2000
INVENTION:	"COMPUTED TOMOGRAPHY APPARATUS WITH AUTOMATIC PARAMETER MODIFICATION TO PREVENT IMPERMISSIBLE OPERATING STATES" (AS AMENDED)

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Applicant herewith amends the above-referenced PCT application as follows, and requests entry of the Amendment prior to examination in the United States National Examination Phase.

IN THE TITLE

Please cancel the present title and substitute the following title therefor:

--"COMPUTED TOMOGRAPHY APPARATUS WITH AUTOMATIC PARAMETER MODIFICATION TO PREVENT IMPERMISSIBLE OPERATING STATES"--.

IN THE SPECIFICATION:

The specification has been amended as set forth in the substitute specification submitted herewith pursuant to 37 C.F.R. §1.125(b). A marked-up copy showing all changes is also submitted herewith. No new matter is added in the substitute specification.

IN THE DRAWINGS:

Please amend each of Figures 1 and 2 as shown on the drawing copies marked in red, attached to the Request for Approval of Drawing Changes filed simultaneously herewith.

IN THE CLAIMS:

Cancel claims 1-18 shown on the amended sheets, and substitute the following claims therefor:

19. A computed tomography apparatus comprising:

a measurement unit adapted to receive an examination subject, said measurement unit, in a scan of said subject, generating data values for said subject;

a control unit connected to said measurement unit for operating said measurement unit during said scan according to a combination of operating parameters;

an image computer supplied with said data values for reconstructing an image of said subject from said data values, said image having an image quality;

a user-operable input unit connected to said control unit allowing a user to enter a selected combination of said operating parameters for conducting a user-intended scan, said selected combination, if implemented, causing an image with a user-intended image quality to be reconstructed; and

said control unit determining whether said selected combination would produce an impermissible operating state of said measurement unit and, if so, said control unit causing at least one of said operating parameters in said selected combination to be altered to a value which permits said user-intended scan to be conducted while avoiding said impermissible operating state and which produces an image of said subject having an

image quality which is not significantly reduced in comparison to said user-intended image quality.

20. A computed tomography apparatus as claimed in claim 19 wherein said control unit automatically sets said altered value of said at least one of said operating parameters in said selected combination, and automatically operates said measurement unit to conduct said scan with said altered value.

21. A computed tomography apparatus as claimed in claim 20 wherein said control unit generates information identifying said altered value which has automatically been set.

22. A computed tomography apparatus as claimed in claim 19 wherein said control unit generates information identifying said altered value, and wherein said control unit must be enabled, by an input entered via said input unit, to conduct said user-intended scan with said altered value.

23. A computed tomography apparatus as claimed in claim 19 wherein said measurement unit is adapted for conducting a spiral scan of said subject, and wherein said measurement unit includes an X-ray source which emits an X-ray beam, a radiation detector disposed in said X-ray beam, and a subject support adapted to receive said subject thereon, said measurement unit rotating said X-ray source and said radiation detector around said subject while effecting a relative longitudinal movement between said X-ray source and said detector, and said subject support, said measurement unit conducting said spiral scan with a defined effective slice thickness during a scan time during which the X-ray source is operated with a tube current, and wherein said control unit, to avoid said impermissible operating state, alters said at least one of said operating parameters in said

selected combination so that an mAs product contributing to a sectional image of the defined effective slice thickness is not significantly reduced in comparison to an mAs product contributing to said sectional image of said defined effective slice thickness in said user-intended scan.

24. A computed tomography apparatus as claimed in claim 23 wherein said spiral scan has a pitch associated therewith, and wherein said image computer reconstructs a sectional image of said subject so that a layer sensitivity profile of the reconstructed sectional image is substantially independent of the pitch, with the mAs product, employed for obtaining the data values from which said reconstructed sectional image is reconstructed, is dependent on the pitch.

25. A computed tomography apparatus as claimed in claim 24 wherein said operating parameters include said scan time and said tube current, and wherein said control unit keeps the product of said tube current and said scan time, in the scan conducted with said altered value, equal to the product of the tube current and the scan time in said selected combination.

26. A computed tomography apparatus as claimed in claim 24 wherein said X-ray source has a focus, with a focus size, from which said X-ray beam is emitted, and further comprising a beam diaphragm for gating said X-ray beam to produce a collimated slice thickness, and wherein said input unit allows entry of at least one of an upper limit value and a lower limit value for at least one operating parameter selected from the group consisting of maximum permissible scan time, minimum mAs product per sectional image, maximum mAs product per sectional image, minimum effective slice thickness, maximum effective slice thickness., minimum collimated slice thickness, maximum collimated slice thickness, minimum rotation time,

maximum rotation time, minimum pitch, maximum pitch, minimum scan length, maximum scan length, minimum waiting time before conducting said scan, maximum waiting time before conducting said scan, and focus size.

27. A computed tomography apparatus as claimed in claim 26 wherein said control unit optimizes the operating parameters in said selected combination relative to at least one optimization goal, dependent on said at least one of said upper limit and said lower limit.

28. A computed tomography apparatus as claimed in claim 27 wherein said control unit optimizes the operating parameters in said selected combination relative to an optimization goal selected from the group consisting of minimum scan time, maximum spatial resolution, maximum temporal resolution, and maximum scan length.

29. A computed tomography apparatus as claimed in claim 27 wherein said control unit optimizes said operating parameters of said selected combination dependent on a plurality of optimization goals, and wherein said control unit ranks the respective optimization goals in said plurality of optimization goals dependent on ranks entered via said input unit.

30. A computed tomography apparatus as claimed in claim 26 wherein said control unit determines whether it is impossible to avoid an impermissible operating state and to comply with said at least one of said upper limit value and said lower limit value and wherein, if compliance is impossible, said control unit makes available a combination of operating parameters which approximate said selected combination without producing an impermissible operating state of said measurement unit.

31. A computed tomography apparatus as claimed in claim 30 wherein, if compliance is impossible, said control unit makes available a plurality of combinations of operating parameters, said combinations being respectively optimized dependent on different optimization goals.

32. A computed tomography apparatus as claimed in claim 30 wherein said control unit automatically operates said measurement unit to conduct said user-intended scan with said combination of operating values which approximates said selected combination.

33. A computed tomography apparatus as claimed in claim 32 wherein said control unit makes information available identifying each value of each operating parameter in said combination of operating parameters which approximates said selected combination, which does not comply with said at least one of said upper limit value and said lower limit value.

34. A computed tomography apparatus as claimed in claim 30 wherein said control unit makes information available identifying any value of any of said operating parameters in said combination of operating parameters which approximates said selected combination, which does not comply with said at least one of said upper limit value and said lower limit value, and wherein said control unit requires enablement, via said input unit, to conduct said user-intended scan using said combination of operating values which approximates said selected combination.

35. A computed tomography apparatus as claimed in claim 19 wherein said control unit generates and makes available a plurality of different combinations of operating parameters, for successive scans of said subject, respectively dependent on different optimization goals for optimizing said operating parameters.

36. A computed tomography apparatus as claimed in claim 19 wherein said control unit ranks said operating parameters dependent on a rank order entered via said input unit, and selects an operating parameter for alteration dependent on its rank order.

37. A computed tomography apparatus as claimed in claim 19 wherein said measurement unit has an X-ray source which emits an X-ray beam from a focus having a focus size, and a radiation detector on which said X-ray beam is incident with an effective slice thickness, and a beam diaphragm disposed for gating said X-ray beam to produce a collimated slice thickness, said X-ray source and said radiation detector being rotatable around said subject to conduct said scan, and wherein said image computer reconstructs a sectional image of said subject, the data values used by said image computer to reconstruct said sectional image having been produced by said measurement unit with an mAs product, and wherein said input unit allows entry of at least one of an upper limit value and a lower limit value for at least one operating parameter selected from the group consisting of maximum permissible scan time, minimum mAs product per sectional image, maximum mAs product per sectional image, minimum effective slice thickness, maximum effective slice thickness, minimum collimated slice thickness, maximum collimated slice thickness, minimum rotation time, maximum rotation time, minimum scan length, maximum scan length, minimum waiting time before conducting said scan, maximum waiting time before conducting said scan and focus size.

38. A computed tomography apparatus as claimed in claim 37 wherein said control unit optimizes the operating parameters in said selected combination relative to at least one optimization goal, dependent on said at least one of said upper limit and said lower limit.

39. A computed tomography apparatus as claimed in claim 38 wherein said control unit optimizes the operating parameters in said selected combination relative to an optimization goal selected from the group consisting of minimum scan time, maximum spatial resolution, maximum temporal resolution, and maximum scan length.

40. A computed tomography apparatus as claimed in claim 38 wherein said control unit optimizes said operating parameters of said selected combination dependent on a plurality of optimization goals, and wherein said control unit ranks the respective optimization goals in said plurality of optimization goals dependent on ranks entered via said input unit.

41. A computed tomography apparatus as claimed in claim 37 wherein said control unit determines whether it is impossible to avoid an impermissible operating state and to comply with said at least one of said upper limit value and said lower limit value and wherein, if compliance is impossible, said control unit makes available a combination of operating parameters which approximate said selected combination without producing an impermissible operating state of said measurement unit.

42. A computed tomography apparatus as claimed in claim 41 wherein, if compliance is impossible, said control unit makes available a plurality of combinations of operating parameters, said combinations being respectively optimized dependent on different optimization goals.

43. A computed tomography apparatus as claimed in claim 41 wherein said control unit automatically operates said measurement unit to conduct said user-intended scan with said combination of operating values which approximates said selected combination.

44. A computed tomography apparatus as claimed in claim 43 wherein said control unit makes information available identifying each value of each operating parameter in said combination of operating parameters which approximates said selected combination, which does not comply with said at least one of said upper limit value and said lower limit value.

45. A computed tomography apparatus as claimed in claim 41 wherein said control unit makes information available identifying any value of any of said operating parameters in said combination of operating parameters which approximates said selected combination, which does not comply with said at least one of said upper limit value and said lower limit value, and wherein said control unit requires enablement, via said input unit, to conduct said user-intended scan using said combination of operating values which approximates said selected combination.

IN THE ABSTRACT:

The Abstract has been amended as follows:

A computed tomography (CT) device has adjustable operational parameters and a control unit and a unit for preselecting a combination of operational parameters for an examination to be carried out. The control unit determines, for the case where a combination of operational parameters which might lead to an impermissible operating state is preselected for an examination to be carried out, a value for at least one operational parameter which deviates from the preselected combination of operational parameters and for which the planned examination can be carried out in a manner avoiding the impermissible operating state without a significant reduction in the image quality by comparison with the preselected combination of operational parameters.

REMARKS:

The present Amendment revises the specification, drawings, claims and Abstract in order to conform to the requirements of United States patent practice. The cancellation of claims 1-18 in favor of the claims submitted herein has been made solely for the purpose of presenting a set of claims in compliance with 35 U.S.C. §112, second paragraph. No change in any claim has been made for the purpose of distinguishing any claim over the teachings of the prior art, and no deviation from the language of claims 1-18 in the claims presented herein is considered as a surrender of any of the subject matter encompassed within the scope of the original claims.

Early consideration on the merits is respectfully requested.

Submitted by,

Mark Bergner (Reg. 45,877)

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Patent Department
6600 Sears Tower
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Chicago, Illinois 60606
Telephone: 312/258-5799
Attorneys for Applicant

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE ABSTRACT

Please amend the Abstract as follows:

[The invention relates to a computer] A computed tomography (CT) device [having] has adjustable operational parameters [(*I*, *T*), which has] and a control unit and [means] a unit for preselecting a combination of operational parameters [(*I*, *T*)] for an examination to be carried out. [In this case, a] The control unit determines, for the case where a combination of operational parameters [(*I*, *T*)] which might lead to an impermissible operating state is preselected for an examination to be carried out, [determines,] a value for at least one operational parameter [(*I*, *T*), a value] which deviates from the preselected combination of operational parameters [(*I*, *T*)] and for which the [envisaged] planned examination can be carried out in a manner avoiding the impermissible operating state without a significant reduction in the image quality by comparison with the preselected combination of operational parameters [(*I*, *T*)].

BOX PCT

IN THE UNITED STATES DESIGNATED OFFICE

OF THE UNITED STATES PATENT AND TRADEMARK OFFICE

UNDER THE PATENT COOPERATION TREATY-CHAPTER II

REQUEST FOR APPROVAL OF DRAWING CHANGES

APPLICANT:	Thomas von der Haar
ATTORNEY DOCKET NO.	P01,0349
INTERNATIONAL APPLICATION NO:	PCT/DE/00/01276
INTERNATIONAL FILING DATE:	April 25, 2000
INVENTION:	"COMPUTED TOMOGRAPHY APPARATUS WITH AUTOMATIC PARAMETER MODIFICATION TO PREVENT IMPERMISSIBLE OPERATING STATES" (AS AMENDED)

Assistant Commissioner for Patents,

Washington, D.C.

S I R:

Applicant herewith requests approval of the drawing changes in Figures 1 and 2, as shown on the drawing copies marked in red attached hereto.

Submitted by,

Mark Bergner (Reg. 45,877)

SCHIFF, HARDIN & WAITE
CUSTOMER NO. 26574
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6600 Sears Tower
233 South Wacker Drive
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Telephone: 312/258-5799
Attorneys for Applicant

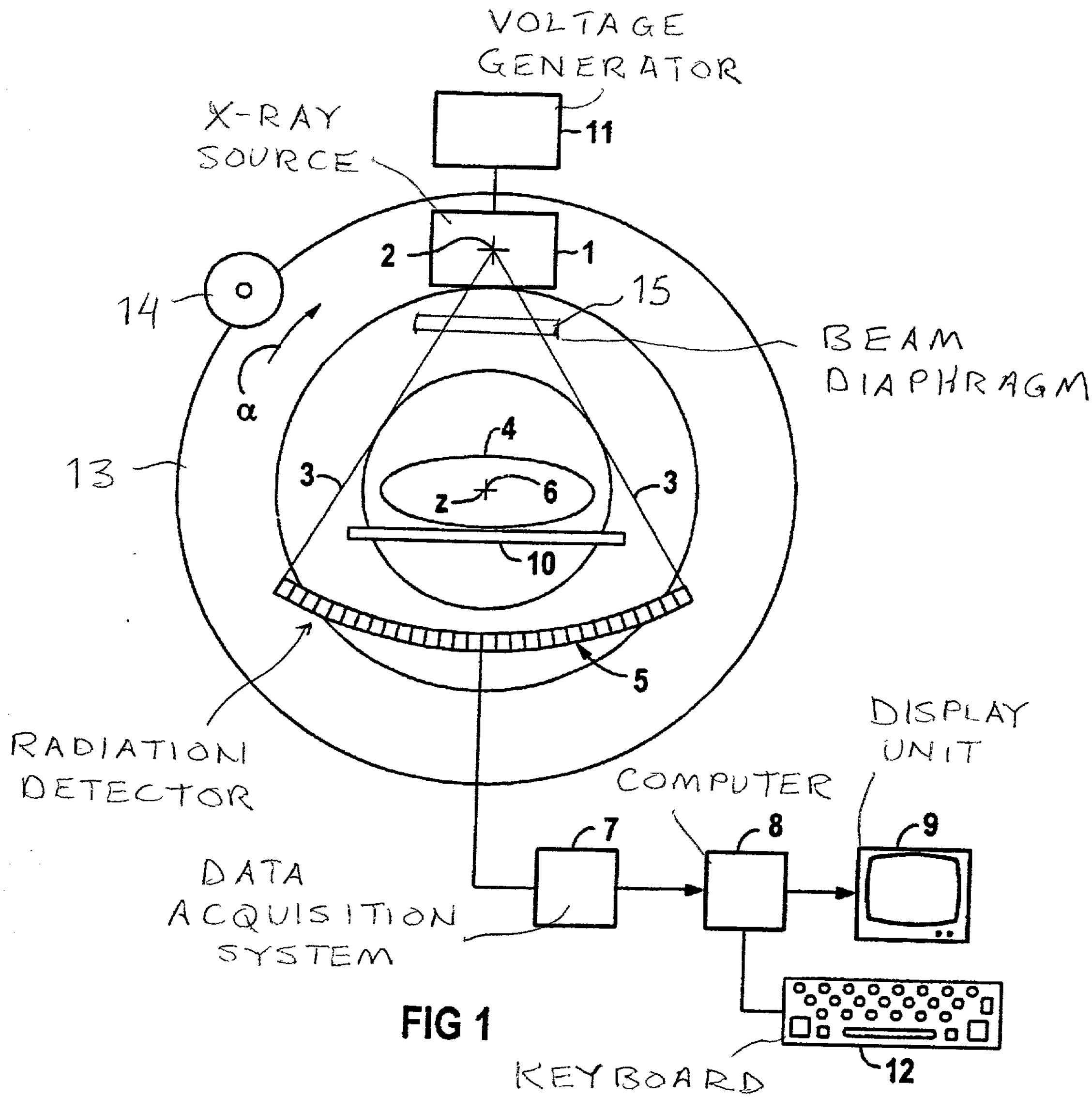
VOLTAGE GENERATOR
11
X-RAY SOURCE
2
1
15
14
BEAM DIAPHRAGM
α
4
13
3
3
z
6
10
5
RADIATION DETECTOR
DISPLAY UNIT
COMPUTER
7
8
9
DATA ACQUISITION SYSTEM
KEYBOARD
12

FIG 1

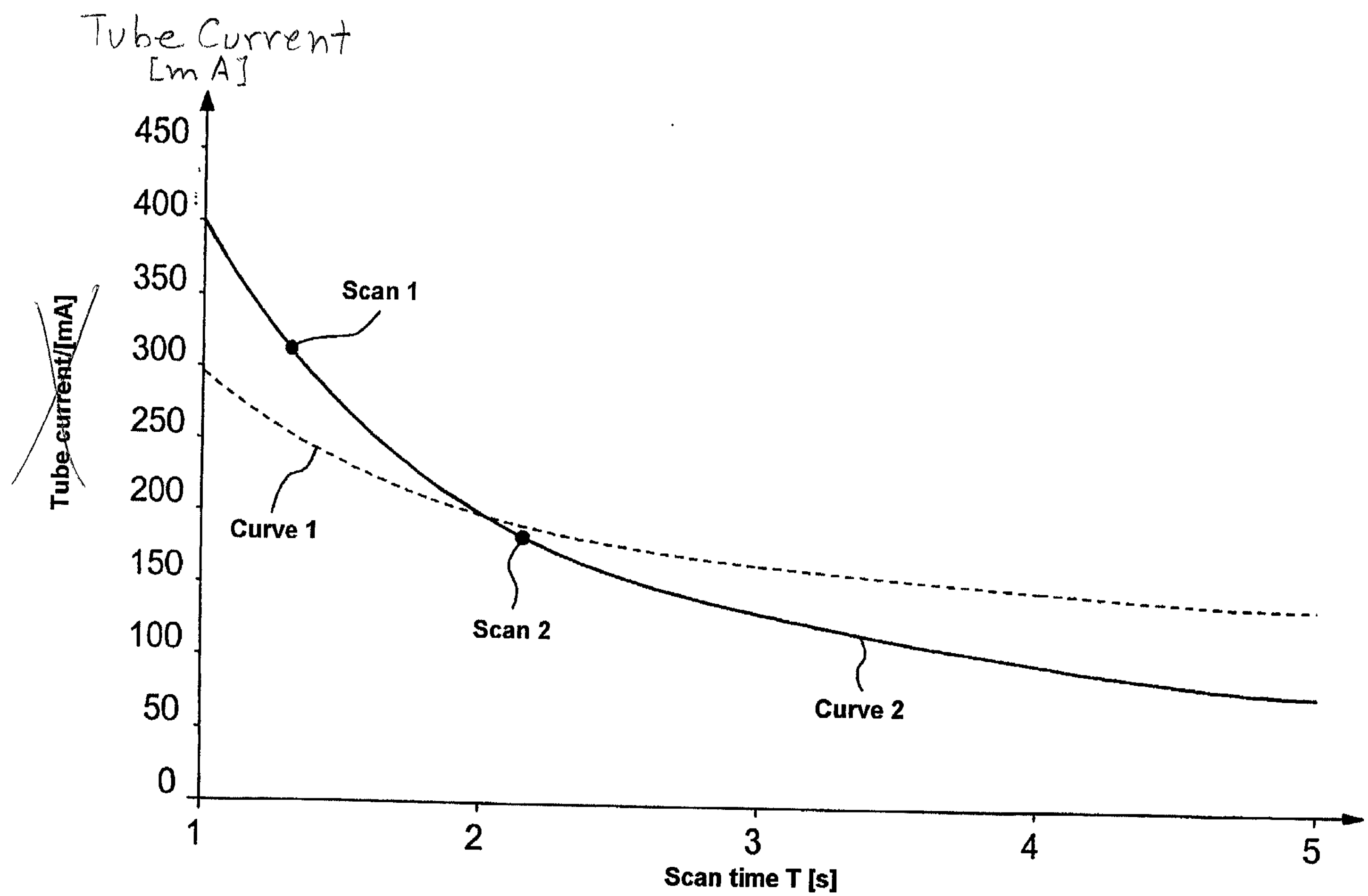
Tube Current
[mA]
~~Tube current/[mA]~~
450
400
350
300
250
200
150
100
50
0
1
2
3
4
5
Scan time T [s]
Scan 1
Scan 2
Curve 1
Curve 2

FIG 2

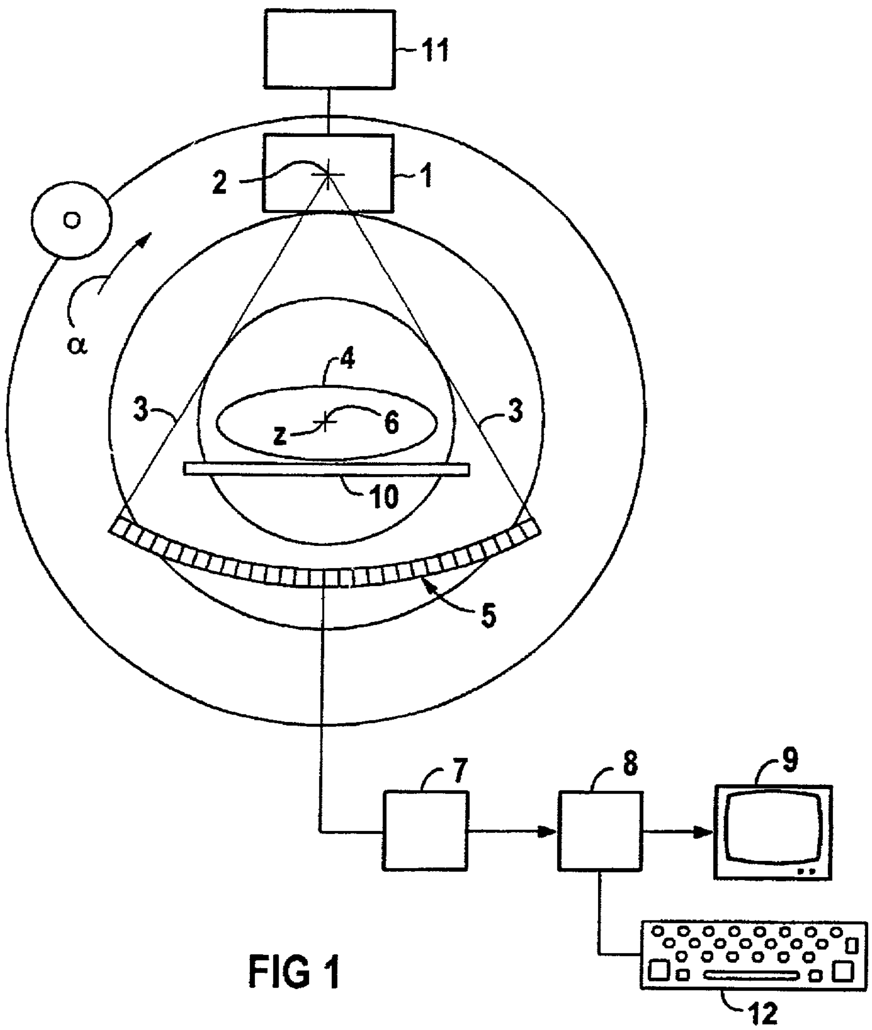

FIG 1

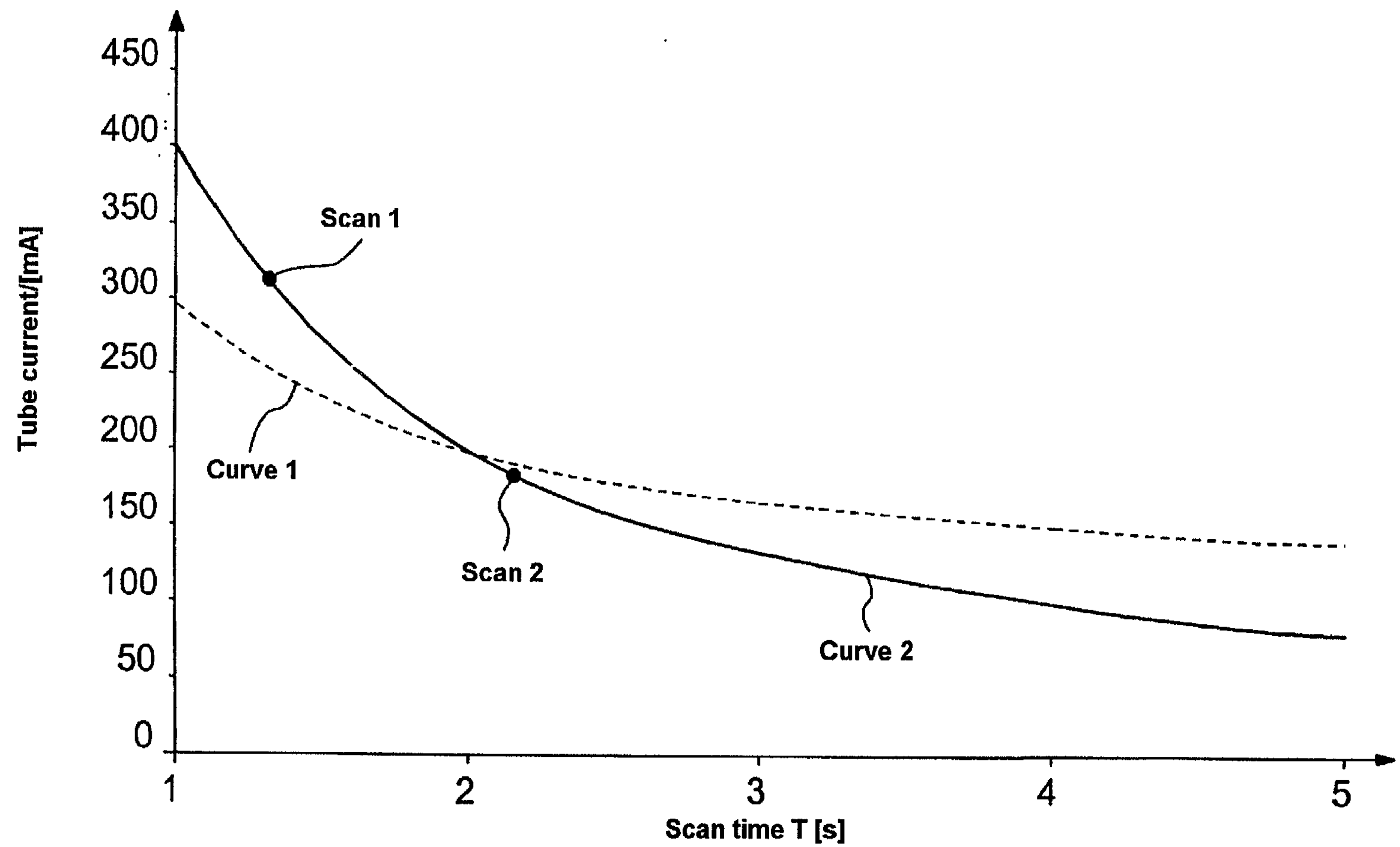
Tube current/[mA]
450
400
350
300
250
200
150
100
50
0
1
2
3
4
5
Scan time T [s]
Scan 1
Scan 2
Curve 1
Curve 2

FIG 2

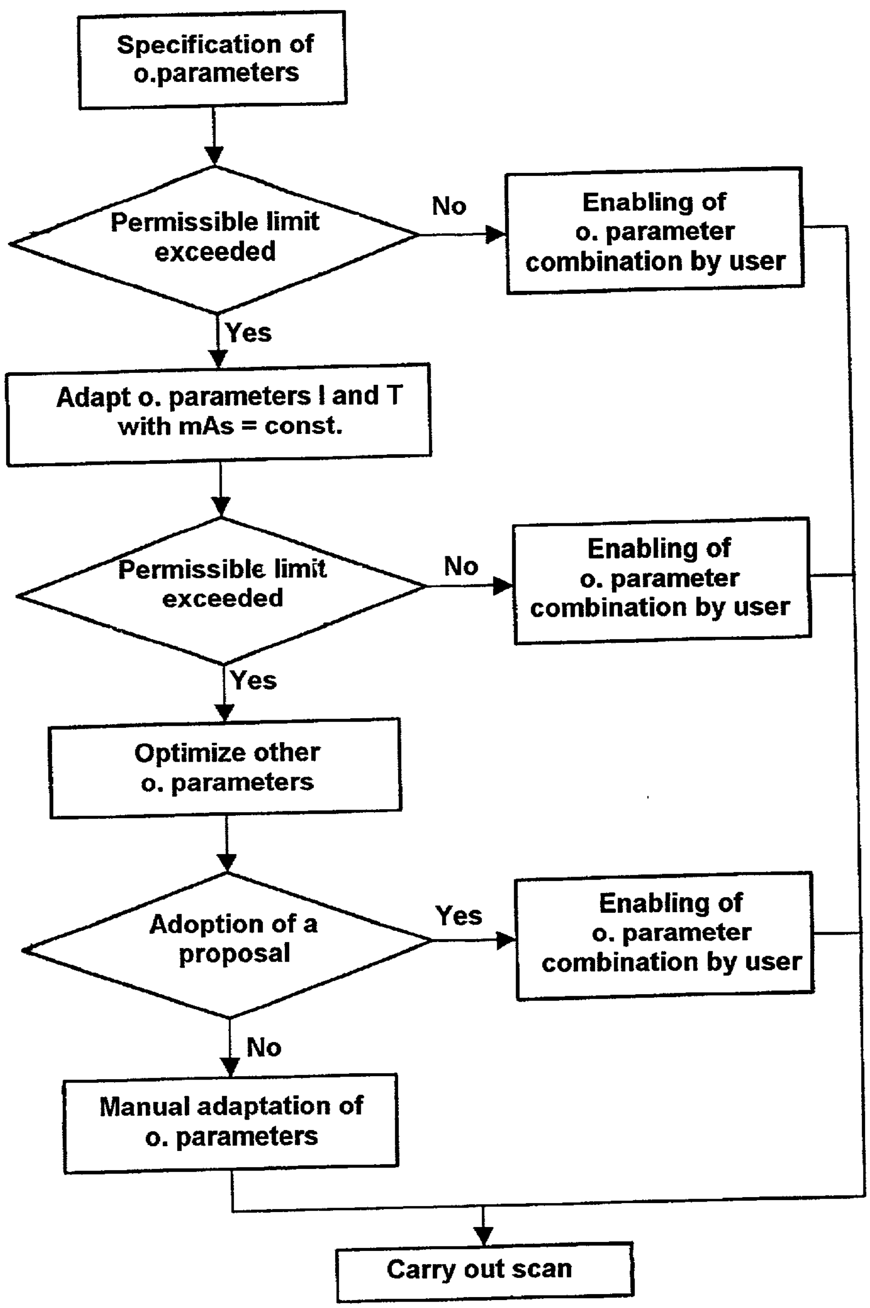
Specification of o.parameters
Permissible limit exceeded
No
Enabling of o. parameter combination by user
Yes
Adapt o. parameters I and T with mAs = const.
Permissible limit exceeded
No
Enabling of o. parameter combination by user
Yes
Optimize other o. parameters
Adoption of a proposal
Yes
Enabling of o. parameter combination by user
No
Manual adaptation of o. parameters
Carry out scan

FIG 3

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3/prts

SUBSTITUTE SPECIFICATION

SPECIFICATION

TITLE

"COMPUTED TOMOGRAPHY APPARATUS WITH AUTOMATIC PARAMETER MODIFICATION TO PREVENT IMPERMISSIBLE OPERATING STATES"

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a CT device of the type having adjustable operational parameters, and a control unit, connected to an input unit for preselecting a combination of operational parameters for an examination to be carried out.

Description of the Prior Art

During examinations with a computed tomography apparatus, it can occur that examinations cannot be carried out with a combination of operational parameters that is desired by the user, on account of technical or user-defined limitations of the permissible values of the operational parameters of the CT device. In particular, the thermal loading capacity of the X-ray source – generally embodied as an X-ray tube – of the CT device has a limiting effect on specific operational parameters (e.g. scan time, i.e. that period of time during which an object under examination is irradiated with X-rays in order to carry out an examination, scan length, i.e. that extent of the object under examination in the direction of the system axis over which an object under examination is scanned with X-rays in order to carry out an examination, tube current, tube voltage, etc.).

European Application 0 809 422 describes a method for establishing and/or correcting exposure errors in X-ray radiographs, in which, during the recording of an X-ray image, a check is made to determine whether the actual exposure rate corresponds to a predicted exposure rate. If this is not

the case, the recording is terminated or suitable recording parameters are corrected with the aim of achieving a correct exposure.

SUMMARY OF THE INVENTION

An object of the present invention is to design a CT device of the type described above wherein a user is provided with a control aid for those examinations for which the user has set a combination of operational parameters which is not at least within the technical limits with regard to the individual operational parameters.

The above object is achieved in accordance with the invention in a computed tomography (CT) device which has adjustable operational parameters and a control unit and a unit for preselecting a combination of operational parameters for an examination to be carried out. The control unit determines, for the case where a combination of operational parameters which might lead to an impermissible operating state is preselected for an examination to be carried out, a value for at least one operational parameter which deviates from the preselected combination of operational parameters and for which the planned examination can be carried out in a manner avoiding the impermissible operating state without a significant reduction in the image quality by comparison with the preselected combination of operational parameters.

Thus, the CT device according to the invention affords a possibility of resolving conflicts for those combinations of operational parameters which do not lie within the technical limits of the CT device and/or within user-defined limit values, with the consequence that the corresponding examination could not actually be carried out. This is because in the case of the CT device according to the invention, a modified value is determined for at least one operational parameter of the preselected combination, which has been changed such that the image quality, in particular the image noise, is maintained as far as possible in comparison with the initially set combination of operational parameters, and so that the CT device is

operated within the permissible technical or user-defined limits. The user thus is enabled by this control aid to carry out an examination which substantially corresponds to the originally intended examination, but which can be carried out without technical limits of the CT device and/or user-defined limit values being exceeded. As used herein "exceed" is not used in the literal sense but rather to mean that a limit value is transgressed, i.e. an upper limit value is exceeded or a lower limit value is undershot.

Of course the changes to the operational parameters which are specified by the control unit are possible only within the technical limits of the CT device. Technical limits include, inter alia: maximum and minimum tube current that can be set, maximum and minimum possible scan time, maximum and minimum pitch that can be set, i.e. the advance in the direction of the system axis per revolution of the radiation source relative to the collimated width of a linear array of detector elements of the detector (collimated layer thickness), etc.

In order to bring about a combination of operational parameters which does not represent an impermissible operating state, the control unit can change one or a number of operational parameters of the chosen combination of operational parameters.

The changes to the operational parameters which are specified by the control unit can either be set automatically (with or without corresponding information of the user) or be presented to the user as a proposal, in the latter case the actual setting of a deviating operational parameter being effected only in response to corresponding enabling by the user. The first-mentioned embodiment, whether with or without information of the user, is advantageous when marginal changes in one or a number of operational parameters are sufficient. By contrast, if relatively large changes are necessary, in particular those which have an effect in the sense of impairing the expected image quality, then the last-mentioned embodiment, which provides for enabling by the user, is advantageous. In this case, the CT

device has a unit which determines whether an automatic change can be effected or whether enabling by the user is required, depending on the operational parameter affected in each case and on the extent of the required change, for example on the basis of a table which contains the corresponding information and is stored in the CT device.

In a preferred embodiment of the invention, the CT device according to the invention is provided for carrying out spiral scans in which an X-ray source rotates around an object under examination and, at the same time, a translational relative movement is effected between the object under examination, and the X-ray source and also a detector. The spiral scan is carried out during a scan time during which the X-ray source is operated with a tube current. The control unit, in the case of an impermissible preselected combination of operational parameters, in order to avoid an impermissible operating state, specifies a value for at least one operational parameter which derived using the specified value for that operational parameter, so that the product of tube current and scan time (mAs product) is not significantly reduced by comparison with the preselected combination of operational parameters.

It is ensured that the *mAs* product used for carrying out the envisaged examination is not significantly reduced by the change in the operational parameters. Since the *mAs* product, which contributes to a reconstructed sectional image (CT image), is crucial to the image noise and hence the image quality (the image noise increases as the *mAs* product decreases), it is ensured that despite the changed operational parameters, no considerable change in the image quality occurs.

For the 180LI or 360LI interpolation which is typically used in the reconstruction of sectional images from spiral scans and is described in the literature, it is difficult to comply with this condition. In these types of interpolation, the layer sensitivity profile is dependent on the pitch, while the *mAs* product is independent of the pitch. Thus, in an embodiment of the

invention an electronic computing device for the reconstruction of sectional images is provided which reconstructs the sectional images in such a way that the slice sensitivity profile of a reconstructed sectional image is at least essentially independent of the pitch, while the *mAs* product serving for obtaining the data on which a sectional image is in each case based depends on the pitch. In this case, the *mAs* product, which contributes to a reconstructed sectional image, is proportional to the product of tube current and scan time, with the consequence that the image noise only depends on the product of tube current and scan time if no other operational parameters are changed. The requirement that no reduction in the image quality is supposed to occur as a result of the specified changes to operational parameters can then be met, in an embodiment of the invention, by the fact that the product of tube current and scan time in the operational parameters prescribed by the control unit is equal to the product of tube current and scan time in the desired combination of operational parameters. This procedure encounters its limits, however, in the case of large pitch values p (guide value $p > 1.5 * n$, where n=1 in the case of a CT device with a detector system having a single linear array of detector elements, and corresponds to the number of simultaneously recorded slices in the case of a CT device with a detector system having a number of linear arrays of detector elements), since image artifacts increase appreciably in that case.

As already mentioned, within the technical limits of the device, the user can additionally set upper or lower limit values for operational parameters within which the changes to the operational parameters which are specified by the control unit must fall. Thus, it is possible to define e.g. a maximum permissible scan time in order to be able to carry out a scan, i.e. an examination, e.g. within a time of holding one's breath. Equally it is possible to define a maximum permissible pitch in order e.g. to limit the intensity of the artifacts in the reconstructed sectional images. Furthermore,

it is possible to define a minimum pitch in order, for example, to prevent a specific temporal resolution from being undershot.

In a further embodiment of the invention, operational parameters can be changed while taking account of an optimization goal, in which case, if a number of optimization aims are present, it is possible to prescribe a rank order of the optimization goals. The optimization goals may be, for example, minimum scan time, maximum spatial resolution, maximum temporal resolution, maximum scan length.

It may occur, on the basis of the preselected combination of operational parameters, while complying with the limit values, it is not possible to determine a combination of operational parameters which represents a permissible operating state, so it is unavoidable for at least one limit value to be exceeded. For this case, in the embodiment of the invention the control unit offers for selection at least one combination of operational parameters which, with at least one limit value not being complied with, is approximated to the preselected combination of operational parameters without an impermissible operating state being present. In this connection, the control unit can offer a number of combinations of operational parameters which are based on various optimization goals, so the user can choose a permissible combination of operational parameters for which one or a number of limit values is or are exceeded in the sense of an optimization goal of the examination. Embodiments of the invention may provide for the control unit to automatically set a value of the corresponding operational parameter which exceeds a limit value, if appropriate with the user being informed, and to carry out the planned examination, or to inform the user about a value of the corresponding operational parameter which exceeds a limit value and to carry out the envisaged examination only when the user enables the performance of the envisaged examination. This last embodiment is expedient principally in those cases in which not complying with the limit value might lead to a reduction in the image quality compared

with the image quality which would be achieved in the case of the preselected combination of operational parameters.

In another embodiment the control unit offers combinations of operational parameters for successive examinations of the same object under examination while taking account of various optimization goals. It is then possible, for example, to carry out an examination with maximum spatial resolution and then an examination with maximum temporal resolution, in succession.

In a further embodiment of the invention a unit for entering a rank order of the operational parameters is provided, and the control unit complies with the rank order of the operational parameters in the event of operational parameters being changed to values which deviate from values of a preselected combination of operational parameters. This means an attempt is made to realize a permissible combination of operational parameters first by changing the operational parameter which is in first place in the rank order. If this is unsuccessful, then the control unit seeks to bring about a permissible combination of operational parameters by changing the operational parameter which is in second place in the rank order, etc. It is thus possible to prescribe a rank order which ensures that the values of specific operational parameters deemed by a user to be particularly significant for the intended examination are changed only when this is unavoidable, by the corresponding operational parameters being placed as far down as possible on the priority list.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic illustration of a computed tomography apparatus constructed and operating in accordance with the principles of the present invention.

Figure 2 shows the relationship between the tube current and the scan time for assistance in explaining the operation of the inventive computed tomography apparatus.

Figure 3 is a flow chart illustrating the operation of the computed tomography apparatus in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A CT device according to the invention is illustrated schematically in Figure 1, this device having an X-ray source 1, e.g. an X-ray tube, with a focus 2, from which a fan-shaped X-ray beam 3 is emitted which proceeds through a diaphragm (not illustrated) and an object 4 under examination, for example a patient, and strikes an arcuate detector 5. The detector 5 is a linear array formed by a row of detector elements. The X-ray source 1 and the detector 5 are mounted on a gantry 13 which is rotatable by a drive 14. The X-ray source 1 and the detector 5 thus form a measurement system which can be rotated around a system axis 6 which is at a right angle to the plane of the drawing in Figure 1, with the result that the object 4 under examination is irradiated from different projection angles α. The detector elements of the detector 5 produce output signals from which a data acquisition system 7 forms measured values, referred to hereinafter as measured projections, which are fed to a computer 8.

A larger volume of the object 4 under examination can be scanned by the measurement system 1, 5 performing a spiral scan of the desired volume. In this case, a relative movement takes place between the measurement arrangement formed by the X-ray source 1 and the detector 5, and the object 4 under examination, in the direction of the system axis 6, which thus simultaneously represents the longitudinal axis of the spiral scan. This occurs preferably by displacement of a support device 10, provided for receiving the object 4 under examination, in the direction of the system axis 6.

A keyboard 12, which enables the CT device to be controlled, is connected to the computer 8, which, in the exemplary embodiment, is at the same time a control unit and performs the control of the CT device (it is also possible to provide a separate computer as a control unit).

The computer 8 also serves, in particular, to set the tube current, and hence the output power, of the X-ray source 1 supplied by a voltage generator 11.

Therefore the computer 8 is in control communication by any suitable means with the drive 14, the voltage generator 11, the support device 10, and the X-ray source 1. Moreover the X-ray source 1 includes, or has connected therewith, a diaphragm 1r for collimating (gating) the X-ray beam. The computer 8 also is in control communication with the diaphragm 15.

The irradiation from different projection angles α is is undertaken to obtain a number of measured projections. To that end, the X-ray source 1 irradiates the object 4 under examination with the X-ray beam 3 emitted at successive positions of the focus 2 which lie on the spiral track described by the focus 2, each position of the focus 2 being assigned to a projection angle and to a z-position on a z-axis corresponding to the system axis 6.

On account of the spiral scan, at most one measured projection can exist with respect to an image plane disposed at a right angle to the system axis 6, this measured projection being recorded with a position of the focus 2 lying in this image plane. In order nevertheless to be able to calculate a sectional image of that layer of the object 4 under examination which is associated with the respective image plane, calculated projections lying in the image plane thus have to be obtained by suitable interpolation methods from measured projections recorded in the vicinity of the image plane, and, as in the case of measured projections, each calculated projection is assigned to a projection angle α and to a z-position with respect to the system axis 6.

From the projections associated with a desired image plane, the computer 8 reconstructs a sectional image according to reconstruction algorithms known per se and represents them on a display unit 9, e.g. a monitor.

The keyboard 12 can be used to set operational parameters of the CT device, e.g.

- Scan time,
- mAs product per sectional image, i.e. the product of that time in which the data on which the sectional image is based were obtained and the tube current *I* set during this time
- effective slice thickness, also referred to as reconstructed slice thickness, i.e. the extent measured in the direction of the system axis – of that region of the object under examination which contributes to the reconstructed image. As an example, the half-value width of the so-called slice sensitivity profile serves as a measure.
- collimated slice thickness, i.e. the extent – set by one or more diaphragms 15 and measured in the direction of the system axis – of an X-ray beam striking the linear array of detector elements,
- rotation time, i.e. the time that elapses during a complete revolution (360°) of the X-ray source,
- pitch (only for spiral scans),
- scan length,
- focus size, i.e. dimensions of the focal spot of the X-ray source 1 from which the X-rays emerge.

If an operator uses the keyboard 12 to enter a combination of operational parameters which is intended to form the basis for the performance of an examination, then this initially represents only a preliminary selection, because the computer 8 checks this combination of operational parameters before the performance of the examination to determine whether the combination might lead to an impermissible operating state of the CT device. To that end, the computer 8 takes the technical limits of the CT device into account as well as user-defined limits for individual

operational parameters, which can likewise be entered via the keyboard 12. Values with respect to the technical limits of the CT device are stored in a memory associated with the computer 8.

If the computer 8 determines that a combination of operational parameters preselected using the keyboard 12 might lead to an impermissible operating state, then it determines, for at least one operational parameter, a value which deviates from the preselected combination of operational parameters and for which the planned examination can be carried out while avoiding the impermissible operating state without a significant reduction in the image quality, by comparison with the preselected combination of operational parameters.

In this connection, communication takes place between the user and the CT device via the keyboard 12 and the display unit 9. A combination of operational parameters with which the CT device finally performs the planned (user-intended) examination is defined during this communication. An additional display unit also may be provided for such communication, with the consequence that the display unit 9 is reserved solely for displaying the reconstructed sectional images.

The way in which this communication proceeds is explained below using the example of the two operational parameters tube current I and scan time T.

The thermal loading capacity of the X-ray source 1 can be described by the two operational parameters tube current I and scan time T. Depending on the thermal preloading and, if appropriate, depending on the focus size and tube voltage of the X-ray source 1 selected via the keyboard 12, the thermal loading capacity varies, which is determined by the computer 8 or a dedicated load computer, assigned to the X-ray source and communicating with the computer 8, taking account of the thermal preloading. The thermal loading capacity is represented as a function of the tube current I and the scan time T as a dashed curve 1 in Figure 2

qualitatively on the basis of a specific preloading of the X-ray source 1. All scans with combinations of the operational parameters I and T which lie below the curve 1 can be carried out, whereas scans with combinations of the operational parameters I and T above the curve 1 would exceed the thermal loading capacity of the X-ray source 1. They thus lead to impermissible operating states for which reason they cannot, therefore, be performed and are blocked by the computer 8.

Generally, there is no mathematically simple relationship between the operational parameters I and T for a given loading capacity, in particular $I \cdot T$ = const. generally does not hold true. Thus, as an example, if the scan time is doubled for a specific thermal loading capacity, then the tube current generally need not be halved, but rather be reduced only by e.g. 20%.

The image quality, i.e. the image noise, of the sectional images generated is essentially determined by the *mAs* product, which contributes to a reconstructed sectional image. By changing the *mAs* product, with otherwise unchanged operational parameters and parameters of the image reconstruction algorithm, the noise in the sectional image is changed, while the same *mAs* product yields at least essentially the same noise and thus approximately the same image quality.

The computer 8 of the CT device according to the invention calculates, on the basis of the data obtained during a spiral scan, sectional images by means of an image reconstruction algorithm in which the layer sensitivity profile of a reconstructed sectional image does not depend significantly on the pitch, whereas the *mAs* product contributing to the sectional image is dependent on the pitch. In such an image reconstruction algorithm, for each projection angle all the measured values associated with this projection angle which lie within a maximum distance from the image plane are incorporated in the reconstruction in a weighted manner. The weighting is according to their spatial distance in the direction of the longitudinal axis of the spiral scanning from the image plane in accordance

with a weighting function. The weighting function is chosen such that the slice thickness is essentially independent of the pitch.

Consequently, the following relationship holds true:

$$I \propto mAs \cdot p = \frac{mAs \cdot L \cdot ROT}{coll \cdot T} \qquad \text{(Equation 1)}$$

In this case:

I: denotes the tube current

P: denotes the pitch

L: denotes the scan length

ROT: denotes the rotation time

coll: denotes the collimated slice thickness

T: denotes the scan type

It is clear from Equation 1 that the *mAs* product contributing to a reconstructed sectional image is proportional to the product $I \cdot T$ of tube current and scan time. Thus, in the reconstruction algorithm employed, the image quality only depends on the product $I \cdot T$ if the other parameters (collimated *coll* and reconstructed layer thickness, scan length *L* and rotation time *ROT*) are not changed. However, image artifacts may increase appreciably in the case of large values of the pitch *p*.

Figure 2 additionally illustrates a solid curve – designated by curve 2 – of constant image quality, for which $I \cdot T$ = const. holds true, with the consequence that, for a sectional image generated with values corresponding to a point on the curve 2, a constant mAs product which is independent of the position of the point on the curve 2 is used, thereby achieving a constant image noise and hence a constant image quality.

Generally, one part of the curve 2 lies above the permissible thermal loading of the X-ray source 1 in accordance with curve 1, and another part lies below it. If as an example a scan – designated by scan 1 – is

considered with a combination of the operational parameters *I* and *T* above curve 1, this scan would be impermissible on account of excessively high thermal loading of the X-ray source 1. The properties of the abovementioned reconstruction algorithm allow the combination of the operational parameters *I* and *T* to be changed, without any loss in image quality, to the extent that the permissible thermal loading in accordance with curve 1 is no longer exceeded. The corresponding combination of the operational parameters *I* and *T* is designated by scan 2. In the case illustrated, the tube current *I* is reduced and the scan time *T* is simultaneously lengthened, the operational parameters for scan 2 being chosen whilst taking account of curve 1 such that they are as close as possible to the originally preselected operational parameters in accordance with scan 1. The reduction in the pitch *p* accompanying the lengthened scan time *T* does not lead to a significant change in the layer sensitivity profile on account of the reconstruction algorithm used.

The changing of the operational parameters so that the loading capacity of the CT system is no longer exceeded, without degrading the image quality, can either be carried out automatically by the computer 8 (with or without a corresponding indication to the user displayed on the display unit 9 by the computer 8) or can be presented to the user as a proposal by the computer 8, in which case the computer 8 displays a possible indication or a proposal, in the exemplary embodiment, on the display unit 9 and a proposal can be adopted by the user through corresponding actuation of the keyboard 12.

Changes in the operational parameters are possible only within the technical limits of the device. Technical limits may include, in addition to the thermal loading capacity of the X-ray source, inter alia: maximum and minimum tube current that can be set, maximum and minimum pitch that can be set, maximum and minimum scan time that can be set.

In the case of the reconstruction algorithms known as 180°LI and 360°LI interpolation algorithms, the procedure described with regard to the setting of the tube current I and the scan time T is not possible since, in the case of these algorithms, the layer sensitivity profile is dependent on the pitch p, whereas the mAs product is independent of the pitch p.

Within the technical limits of the CT device, by means of the keyboard 12, the user can additionally set user-defined limit values with regard to the operational parameters within which a change in the respective operational parameter is only possible in that case: thus, as an example, it is possible to define a maximum permissible scan time in order to be able to carry out the scan e.g. while holding one's breath. Equally, it is possible to define a maximum permissible pitch in order e.g. to limit the artifact intensity. Finally, it is possible to define a minimum pitch in order e.g. not to fall below a specific temporal resolution.

These user-defined limits either cannot be exceeded at all, or can only be exceeded after confirmation of an indication in this respect which is displayed on the display unit 9 by the computer, by corresponding actuation of the keyboard 12.

Instead of exceeding the technical or user-defined limits, the computer 8 can perform a change in operational parameters other than those (I, T) mentioned above, in order to enable a desired scan. Thus, as an example, it is possible to change the mAs product contributing to the reconstructed sectional image, the effective slice thickness, the focus size, the rotation time or the waiting time that influences the thermal loading capacity and hence the maximum permissible scan time, before the scan. Such changes can again be effected automatically or performed by the computer 8 only after confirmation of an indication in this respect which is displayed on the display unit 9 by the computer 8, by corresponding actuation of the keyboard 12.

It is also possible to change a number of operating parameters in order to enable a desired scan. In this case, protocols concerning the order

in which the individual operational parameters are to be changed are stored in the computer 8, for example in the memory provided for the technical limit values of the CT device. As an alternative, said order may be influenced or determined by the user by means of the keyboard 12.

Thus, it may be expedient, for example in the event of excessively high loading, for the computer 8 to first reduce the tube current *I* while simultaneously lengthening the scan time. If the scan time reaches a maximum permissible scan time before the loading falls below the permissible thermal loading of the X-ray source 1, then the computer 8, in order to enable the scan, switches e.g. to a larger focus of the X-ray source 1. If this still does not suffice to bring about a permissible operating state, the computer 8 may additionally reduce e.g. the *mAs* product.

Figure 3 diagrammatically illustrates the described method of operation of a CT device according to the invention in the form of a flow diagram, to be precise for the case where changes of operational parameters require enabling by the user. In this case, O. parameters denotes operational parameters in Figure 3. The term “permissible limit” encompasses both technical limits of the CT device and limit values defined by the user within these limits.

The stepwise procedure already described above is described, according to which, in the case of a limit being exceeded, firstly a change is made to the operational parameters tube current I and scan time T under the condition mAs = const., and, if this change does not suffice, other operational parameters are optimized while taking account of the limits. If a useable combination of operational parameters cannot be realized in this way, then it becomes clear from Figure 3 that it is then incumbent upon the user to manually adapt operational parameters in order to bring about a situation which enables a scan to be carried out.

The method of operation of the CT device according to the invention was described above for the case where a single scan is to be effected.

However, it applies equally to cases in which a sequence of scans is to be performed, whether with the scans directly succeeding one another, or with the scans being separated from one another by time intervals.

The invention, though this is particularly advantageous, is not restricted to the exemplary embodiment of spiral scans on the basis of a reconstruction algorithm in which the slice sensitivity profile of a reconstructed sectional image does not depend significantly on the pitch, whereas the *mAs* product contributing to the sectional image is dependent on the pitch. The invention also can be employed in conjunction with any other type of scan which does not involve spiral scans, for example, individual planar scans or sequences of planar scans (sequential scan).

In the exemplary embodiment a CT device with a detector having a single linear array of detector elements is described. However, the invention is not restricted to CT devices with such detectors, but rather also encompasses CT devices with detectors having a number of linear arrays of detector elements (multi-linear-array detectors) and also CT devices with detectors having a multiplicity of detector elements arranged in a(matrix array detector).

The invention was explained above using the example of a third-generation CT device. However, it can also be employed in fourth-generation CT devices which, instead of an arcuate detector that can be adjusted with the X-ray source about the system axis, has a stationary ring of detector elements.

The invention can be used both in the medical field and in non-medical fields.

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SPECIFICATION

TITLE

"COMPUTED TOMOGRAPHY APPARATUS WITH AUTOMATIC PARAMETER MODIFICATION TO PREVENT IMPERMISSIBLE OPERATING STATES"

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a CT device of the type having adjustable operational parameters, and [which has] a control unit, [wherein means] connected to an input unit for preselecting a combination of operational parameters for an examination to be carried out [are provided].

Description of the Prior Art

During examinations with a computed tomography apparatus [computer tomographs], it can [happen] occur that examinations cannot be carried out with a combination of operational parameters that is desired by the user, on account of technical or user-defined limitations of the permissible values of the operational parameters of the CT device. In particular, the thermal loading capacity of the X-ray source – generally embodied as an X-ray tube – of the CT device has a limiting effect on specific operational parameters (e.g. scan time, i.e. that period of time during which an object under examination is irradiated with X-rays in order to carry out an examination, scan length, i.e. that extent of the object under examination in the direction of the system axis over which an object under examination is scanned with X-rays in order to carry out an examination, tube current, tube voltage, etc.).

[EP-A-0 809 422] European Application 0 809 422 describes a method for establishing and/or correcting exposure errors in X-ray radiographs, in which, during the recording of an X-ray image, a check is made to determine whether the actual exposure rate corresponds to a

predicted exposure rate. If this is not the case, the recording is terminated or suitable recording parameters are corrected with the aim of achieving a correct exposure.

SUMMARY OF THE INVENTION

[The] <u>An object of the present</u> invention is [based on the object of designing] <u>to design</u> a CT device of the type [mentioned in the introduction in such a way that] <u>described above wherein</u> a user is provided with a control aid for those examinations for which the user has set a combination of operational parameters which [does] <u>is</u> not [lie] at least within the technical limits with regard to the individual operational parameters.

[According to the invention, this object is achieved by means of a CT device having the features of patent claim 1.]

<u>The above object is achieved in accordance with the invention in a computed tomography (CT) device which has adjustable operational parameters and a control unit and a unit for preselecting a combination of operational parameters for an examination to be carried out. The control unit determines, for the case where a combination of operational parameters which might lead to an impermissible operating state is preselected for an examination to be carried out, a value for at least one operational parameter which deviates from the preselected combination of operational parameters and for which the planned examination can be carried out in a manner avoiding the impermissible operating state without a significant reduction in the image quality by comparison with the preselected combination of operational parameters.</u>

Thus, the CT device according to the invention affords a possibility of resolving conflicts for those combinations of operational parameters which do not lie within the technical limits of the CT device and/or within user-defined limit values [(patent claim 8)], with the consequence that the corresponding examination could not actually be carried out. This is because in the case of the CT device according to the invention, a <u>modified</u>

value is determined for at least one operational parameter of the preselected combination, which [value] has been changed such that[, on the one hand,] the image quality, in particular the image noise, is maintained as far as possible in comparison with the initially set combination of operational parameters, and[, on the other hand,] so that the CT device is operated within the permissible technical or user-defined limits. The [respective] user [is] thus is enabled by [a] this control aid to carry out an examination which [ultimately at least essentially] substantially corresponds to the [examination that he] originally intended examination, but which can be carried out without technical limits of the CT device and/or user-defined limit values being exceeded[, exceed in this case not being intended to be understood]. As used herein "exceed" is not used in the literal sense but rather to mean [the effect] that a limit value is transgressed, [that is to say] i.e. an upper limit value is exceeded or a lower limit value is undershot.

[It goes without saying that] Of course the changes to the operational parameters which are specified by the control unit are possible only within the technical limits of the CT device. Technical limits include, inter alia: maximum and minimum tube current that can be set, maximum and minimum possible scan time, maximum and minimum pitch that can be set, i.e. the advance in the direction of the system axis per revolution of the radiation source relative to the collimated width of a linear array of detector elements of the detector (collimated layer thickness), etc.

In order to bring about a combination of operational parameters which does not represent an impermissible operating state, the control unit can change one or a [plurality] number of operational parameters of the chosen combination of operational parameters.

The changes to the operational parameters which are specified by the control unit can either be set automatically (with or without corresponding information of the user) or be presented to the user as a proposal, in the latter case the actual setting of a deviating operational parameter being

effected only in response to corresponding enabling by the user. The first-mentioned embodiment [variant], whether with or without information of the user, is advantageous when marginal changes in one or a [plurality] number of operational parameters are sufficient. By contrast, if relatively large changes are necessary, in particular those which have an effect in the sense of impairing the expected image quality, then the last-mentioned embodiment [variant], which provides for enabling by the user, is advantageous. In this case, [it may be provided that] the CT device has a unit [means] which [decide] determines whether an automatic change can be effected or whether enabling by the user is required, depending on the operational parameter affected in each case and on the extent of the required change, for example on the basis of a table which contains the corresponding information and is stored in the CT device.

In [accordance with one particularly] a preferred [variant] embodiment of the invention, the CT device according to the invention is provided for carrying out spiral scans in which an X-ray source rotates around an object under examination and, at the same time, a translational relative movement is effected between the object under examination, [on the one hand,] and the X-ray source and also a detector[, on the other hand, wherein the]. The spiral scan is carried out during a scan time during which the X-ray source is operated with a tube current[, and wherein the]. The control unit, in the case of an impermissible preselected combination of operational parameters, in order to avoid an impermissible operating state, specifies a value for [the] at least one operational parameter which derived [results] using the [value] specified value for [the at least one] that operational parameter, so that the product of tube current and scan time (mAs product) is not significantly reduced by comparison with the preselected combination of operational parameters.

It is ensured that the *mAs* product used for carrying out the envisaged examination is not significantly reduced by the change in the operational

parameters. Since the *mAs* product, which contributes to a reconstructed sectional image (CT image), is crucial to the image noise and hence the image quality (the image noise increases as the *mAs* product decreases), it is ensured that despite the changed operational parameters, no considerable change in the image quality occurs.

[Since, for] For the 180LI or 360LI interpolation which is typically used in the reconstruction of sectional images from spiral scans and is described in the literature, it is difficult to comply with this condition [– in]. In these types of interpolation, the layer sensitivity profile is dependent on the pitch, while the *mAs* product is independent of the pitch [-, one]. Thus, in an embodiment of the invention [provides for] an electronic computing device for the reconstruction of sectional images[, to be] is provided which reconstructs the sectional images in such a way that the [layer] slice sensitivity profile of a reconstructed sectional image is at least essentially independent of the pitch, while the *mAs* product serving for obtaining the data on which a sectional image is in each case based depends on the pitch. In this case, the *mAs* product, which contributes to a reconstructed sectional image, is proportional to the product of tube current and scan time, with the consequence that the image noise only depends on the product of tube current and scan time if no other operational parameters are changed. The requirement that no reduction in the image quality is supposed to occur as a result of the specified changes to operational parameters can then be met, in [accordance with one variant] an embodiment of the invention, by the fact that the product of tube current and scan time in the [case of the] operational parameters prescribed by the control unit is equal to the product of tube current and scan time in [the case of] the desired combination of operational parameters. This procedure encounters its limits, however, in the case of large pitch values p (guide value $p > 1.5 * n$, where n=1 in the case of a CT device with a detector system having a single linear array of detector elements, and corresponds to the number of simultaneously recorded

[layers] slices in the case of a CT device with a detector system having a [plurality] number of linear arrays of detector elements), since image artifacts increase appreciably in that case.

As already mentioned, within the technical limits of the device, [in accordance with patent claim 8,] the user can additionally set upper or lower limit values for operational parameters within which the changes to the operational parameters which are specified by the control unit must [range] fall. Thus, it is possible to define e.g. a maximum permissible scan time in order to be able to carry out a scan, i.e. an examination, e.g. within a time of holding one's breath. Equally it is possible to define a maximum permissible pitch in order e.g. to limit the intensity of the artifacts in the reconstructed sectional images. Furthermore, it is possible to define a minimum pitch in order, for example, to prevent a specific temporal resolution from being undershot.

In [accordance with one variant] a further embodiment of the invention, operational parameters can be changed [whilst] while taking account of an optimization [aim] goal, in which case, if a [plurality] number of optimization aims are present, it is possible to prescribe a rank order of the optimization [aims] goals. The optimization [aims provided] goals may be, for example, minimum scan time, maximum spatial resolution, maximum temporal resolution, maximum scan length.

[If] It may occur, on the basis of the preselected combination of operational parameters, [whilst] while complying with the limit values, it is not possible to determine a combination of operational parameters which represents a permissible operating state, so it is unavoidable for at least one limit value to be exceeded. For this case, [one variant] in the embodiment of the invention [provides for] the control unit [to offer] offers for selection at least one combination of operational parameters which, with at least one limit value not being complied with, is approximated to the [respective] preselected combination of operational parameters without an impermissible

operating state being present. In this connection, [it may be provided that] the control unit can offer [offers] a [plurality] number of combinations of operational parameters which are based on various optimization [aims] goals, [with the result that] so the user can choose a permissible combination of operational parameters for which one or a [plurality] number of limit values is or are exceeded in the sense of an optimization [aim corresponding to the respective case] goal of the examination. Embodiments of the invention may provide for the control unit to automatically set a value of the corresponding operational parameter which exceeds a limit value, if appropriate with the user being informed, and to carry out the [envisaged] planned examination, or to inform the user about a value of the corresponding operational parameter which exceeds a limit value and to carry out the envisaged examination only when the user enables the performance of the envisaged examination. This last embodiment is expedient principally in those cases in which not complying with the limit value might lead to a reduction in the image quality compared with the image quality which would be achieved in the case of the preselected combination of operational parameters.

[One variant of the invention provides for] In another embodiment the control unit [to offer] offers combinations of operational parameters for successive examinations of the same object under examination [whilst] while taking account of various optimization [aims] goals. It is then possible, for example, [successively] to carry out [firstly] an examination with maximum spatial resolution and then an examination with maximum temporal resolution, in succession.

[A] In a further [variant] embodiment of the invention [provides] a unit for entering [means for inputting] a rank order of the operational parameters [are] is provided, and the control unit complies with the rank order of the operational parameters in the event of operational parameters being changed to values which deviate from values of a preselected combination of operational parameters[, i.e.]. This means an attempt is made to realize

a permissible combination of operational parameters first [of all] by changing the operational parameter which is in first place in the rank order. If this is unsuccessful, then the control unit seeks to bring about a permissible combination of operational parameters by changing the operational parameter which is in second place in the rank order, etc. It is thus possible to prescribe a rank order which ensures that the values of specific operational parameters deemed by a user to be particularly significant for the [respective] <u>intended</u> examination [to be carried out] are changed only when this is unavoidable, by the corresponding operational parameters being placed as far down as possible on the priority list.

[The invention is explained by way of example below with reference to the accompanying drawings, in which:

Figure 1 shows a CT device according to the invention in a diagrammatic illustration,

Figure 2 shows a diagram illustrating the relationship between tube current and scan time, and

Figure 3 shows a flow diagram illustrating the function of the CT device in accordance with Figure 1.]

<u>DESCRIPTION OF THE DRAWINGS</u>

<u>Figure 1 is a schematic illustration of a computed tomography apparatus constructed and operating in accordance with the principles of the present invention.</u>

<u>Figure 2 shows the relationship between the tube current and the scan time for assistance in explaining the operation of the inventive computed tomography apparatus.</u>

<u>Figure 3 is a flow chart illustrating the operation of the computed tomography apparatus in accordance with the invention.</u>

<u>DESCRIPTION OF THE PREFERRED EMBODIMENTS</u>

A CT device according to the invention is illustrated [roughly diagrammatically] <u>schematically</u> in Figure 1, [said] <u>this</u> device having an X-

ray source 1, e.g. an X-ray tube, with a focus 2, from which [emerges] a fan-shaped X-ray beam 3 is emitted which [is inserted] proceeds through a diaphragm (not illustrated)[, penetrates through] and an object 4 under examination, for example a patient, and [impinges on] strikes an arcuate detector 5. The [latter comprises] detector 5 is a [detector] linear array formed by a row of detector elements. The X-ray source 1 and the detector 5 are mounted on a gantry 13 which is rotatable by a drive 14. The X-ray source 1 and the detector 5 thus form a measurement system which can be rotated [about] around a system axis 6 which is at a right [angles] angle to the plane of the drawing in Figure 1, with the result that the object 4 under examination is irradiated [under] from different projection angles α. The detector elements of the detector 5 produce output signals [in this case and] from which [said output signals] a data acquisition system 7 forms measured values [which are], referred to hereinafter as measured projections, [and] which are fed to a computer 8.

A larger volume of the object 4 under examination can be scanned by the measurement system 1, 5 performing a spiral scan of the desired volume. In this case, a relative movement takes place between the measurement arrangement [comprising] formed by the X-ray source 1 and the detector 5, [on the one hand,] and the object 4 under examination, [on the other hand,] in the direction of the system axis 6, which thus simultaneously represents the longitudinal axis of the spiral scan[,]. This occurs preferably by displacement of a [mounting] support device 10, provided for receiving the object 4 under examination, in the direction of the system axis 6.

A keyboard 12, which enables the CT device to be controlled, is connected to the computer 8, which, in [the case of] the exemplary embodiment [described], is at the same time a control unit and performs the control of the CT device (it is also possible to provide a separate computer as a control unit).

The computer 8 also serves, in particular, to set the tube current, and hence the output power, of the X-ray source 1 supplied by a <u>voltage</u> generator [circuit] 11.

<u>Therefore the computer 8 is in control communication by any suitable means with the drive 14, the voltage generator 11, the support device 10, and the X-ray source 1. Moreover the X-ray source 1 includes, or has connected therewith, a diaphragm 1r for collimating (gating) the X-ray beam. The computer 8 also is in control communication with the diaphragm 15.</u>

The irradiation [under] <u>from</u> different projection angles α is [effected with the aim of obtaining] <u>undertaken to obtain a number of</u> measured projections. To that end, the X-ray source 1 irradiates the object 4 under examination with the X-ray beam 3 [emerging from] <u>emitted at</u> successive positions of the focus 2 which lie on the spiral track described by the focus 2, each position of the focus 2 being assigned to a projection angle and to a z-position on a z-axis corresponding to the system axis 6.

On account of the spiral scan, at most one measured projection can exist with respect to an image plane [running] <u>disposed</u> at <u>a</u> right [angles] <u>angle</u> to the system axis 6, [which] <u>this</u> measured projection [was] <u>being</u> recorded with a position of the focus 2 lying in this image plane. In order nevertheless to be able to calculate a sectional image of that layer of the object 4 under examination which is associated with the respective image plane, calculated projections lying in the image plane thus have to be obtained by suitable interpolation methods from measured projections recorded in the vicinity of the image plane, and, as in the case of measured projections, each calculated projection is assigned to a projection angle α and to a z-position with respect to the system axis 6.

From the projections associated with a [respectively] desired image plane, the computer 8 reconstructs a sectional image according to reconstruction algorithms known per se and represents them on a display unit 9, e.g. a monitor.

The keyboard 12 can be used to set operational parameters of the CT device, e.g.

- Scan time,
- mAs product per sectional image, i.e. the product of that time in which the data on which the sectional image is based were obtained and the tube current *I* set during this time
- effective [layer] slice thickness, also referred to as reconstructed [layer] slice thickness, i.e. the extent measured in the direction of the system axis – of that region of the object under examination which contributes to the reconstructed image. [By way of] As an example, the half-value width of the so-called [layer] slice sensitivity profile serves as a measure.
- collimated [layer] slice thickness, i.e. the extent – set by [means of corresponding ray] one or more diaphragms 15 and measured in the direction of the system axis – of an X-ray beam [impinging on a] striking the linear array of detector elements,
- rotation time, i.e. the time that elapses during a complete revolution (360°) of the X-ray source,
- pitch (only for spiral scans),
- scan length,
- focus size, i.e. dimensions of the focal spot of the X-ray source 1 from which the X-rays emerge.

If [a user] an operator uses the keyboard 12 to [input] enter a combination of operational parameters which is intended to form the basis for the performance of an examination, then this initially represents only a preliminary selection, because the computer 8 checks this combination of operational parameters before the performance of the examination to determine whether [said] the combination might lead to an impermissible operating state of the CT device. To that end, the computer 8 [on the one

hand considers] takes the technical limits of the CT device[, and on the other hand it considers] into account as well as user-defined limits for individual operational parameters, which can likewise be [input by means of] entered via the keyboard 12. Values with respect to the technical limits of the CT device are stored in a memory associated with the computer 8.

If the computer 8 [ascertains] determines that a combination of operational parameters preselected using the keyboard 12 might lead to an impermissible operating state, then it determines, for at least one operational parameter, a value which deviates from the preselected combination of operational parameters and for which the planned examination can be carried out [whilst] while avoiding [an] the impermissible operating state without a significant reduction in the image quality, by comparison with the preselected combination of operational parameters.

In this connection, communication takes place between the user and the CT device [by means of] via the keyboard 12 and the display unit 9[, a]. A combination of operational parameters with which the CT device finally performs the planned (user-intended) examination [being] is defined during [said] this communication. An additional display unit [may] also [possibly] may be provided for [the purposes of] such communication, with the consequence that the display unit 9 is [then] reserved solely for displaying the reconstructed sectional images.

The way in which this communication proceeds is explained below using the example of the two operational parameters tube current I and scan time T.

The thermal loading capacity of the X-ray source 1 can be described by the two operational parameters tube current I and scan time T. Depending on the thermal preloading and, if appropriate, depending on the focus size and tube voltage of the X-ray source 1 selected via the keyboard 12, the [present] thermal loading capacity varies, which is determined by the computer 8 or a [particular] dedicated load computer, assigned to the X-ray

source and communicating with the computer 8, taking account of the thermal preloading. The [present] thermal loading capacity is represented as a function of the tube current I and the scan time T as a dashed curve 1 in Figure 2 qualitatively on the basis of a specific preloading of the X-ray source 1. All scans with combinations of the operational parameters I and T which lie below the curve 1 can be carried out, whereas scans with combinations of the operational parameters I and T above the curve 1 would exceed the thermal loading capacity of the X-ray source 1. They thus lead to impermissible operating states for which reason they cannot, therefore, be performed and are blocked by the computer 8.

Generally, there is no mathematically simple relationship between the operational parameters I and T for a given loading capacity, in particular $I \cdot T$ = const. generally does not hold true. Thus, [by way of] as an example, if the scan time is doubled for a specific thermal loading capacity, then the tube current generally need not be halved, but rather be reduced only by e.g. 20%.

The image quality, i.e. the image noise, of the sectional images generated is essentially determined by the *mAs* product, which contributes to a reconstructed sectional image. By changing the *mAs* product, with otherwise unchanged operational parameters and parameters of the image reconstruction algorithm, the noise in the sectional image is changed, while the same *mAs* product yields at least essentially the same noise and thus approximately the same image quality.

The computer 8 of the CT device according to the invention calculates, on the basis of the data obtained during a spiral scan, sectional images by means of an image reconstruction algorithm in which the layer sensitivity profile of a reconstructed sectional image does not depend significantly on the pitch, whereas the *mAs* product contributing to the sectional image is dependent on the pitch. In such an image reconstruction algorithm, [the procedure is such that, with respect to] for each projection

angle[,] all the measured values [which are] associated with this projection angle [and] which lie within a maximum distance from the image plane are incorporated in the reconstruction in a weighted manner. The weighting is according to their spatial distance in the direction of the longitudinal axis of the spiral scanning from the image plane in accordance with a weighting function[, and that the]. The weighting function is chosen such that the [layer] slice thickness is [at least] essentially independent of the pitch.

Consequently, the following relationship holds true:

$$I \propto mAs \cdot p = \frac{mAs \cdot L \cdot ROT}{coll \cdot T} \qquad \text{(Equation 1)}$$

In this case:

I:	denotes the tube current
P:	denotes the pitch
L:	denotes the scan length
ROT:	denotes the rotation time
coll:	denotes the collimated [layer] slice thickness
T:	denotes the scan type

It [becomes] is clear from Equation 1 that the *mAs* product contributing to a reconstructed sectional image is proportional to the product $I \cdot T$ of tube current and scan time. Thus, in the reconstruction algorithm employed, the image quality only depends on the product $I \cdot T$ if the other parameters (collimated *coll* and reconstructed layer thickness, scan length *L* and rotation time *ROT*) are not changed. However, image artifacts may increase appreciably in the case of large values of the pitch *p*.

Figure 2 additionally illustrates a solid curve – designated by curve 2 – of constant image quality, for which $I \cdot T$ = const. holds true, with the consequence that, for a sectional image generated with values corresponding to a point on the curve 2, a constant mAs product which is

independent of the position of the point on the curve 2 is used, thereby achieving a constant image noise and hence a constant image quality.

Generally, one part of the curve 2 lies above the permissible thermal loading of the X-ray source 1 in accordance with curve 1, and another part lies below it. If [we consider, by way of] as an example[,] a scan – designated by scan 1 – is considered with a combination of the operational parameters *I* and *T* above curve 1, this scan would be impermissible on account of excessively high thermal loading of the X-ray source 1. The properties of the abovementioned reconstruction algorithm [now make it possible to change] allow the combination of the operational parameters *I* and *T* to be changed, without any [losses] loss in image quality, to the extent that the permissible thermal loading in accordance with curve 1 is no longer exceeded. The corresponding combination of the operational parameters *I* and *T* is designated by scan 2. In the case illustrated, the tube current *I* is reduced and the scan time *T* is simultaneously lengthened, the operational parameters for scan 2 being chosen whilst taking account of curve 1 such that they are as close as possible to the originally preselected operational parameters in accordance with scan 1. The reduction in the pitch *p* accompanying the lengthened scan time *T* does not lead to a significant change in the layer sensitivity profile on account of the reconstruction algorithm used.

The changing of the operational parameters [to the effect] so that the loading capacity of the CT system is no longer exceeded, without [this being associated with losses of] degrading the image quality, can either be carried out automatically by the computer 8 (with or without a corresponding indication to the user displayed on the display unit 9 by the computer 8) or can be presented to the user as a proposal by the computer 8, in which case the computer 8 displays a possible indication or a proposal, in the [case of the] exemplary embodiment [described], on the display unit 9 and a proposal

can be adopted by the user through corresponding actuation of the keyboard 12 [as enable means].

Changes in the operational parameters are possible only within the technical limits of the device. Technical limits may include, in addition to the thermal loading capacity of the X-ray source, inter alia: maximum and minimum tube current that can be set, maximum and minimum pitch that can be set, maximum and minimum scan time that can be set.

In the case of the reconstruction algorithms known as 180°LI and 360°LI interpolation algorithms, the procedure described with regard to the setting of the tube current I and the scan time T is not possible since, in the case of these algorithms, the layer sensitivity profile is dependent on the pitch p, whereas the *mAs* product is independent of the pitch p.

Within the technical limits of the CT device, by means of the keyboard 12, the user can additionally set user-defined limit values with regard to the operational parameters within which a change in the respective operational parameter is only possible in that case: thus, [by way of] as an example, it is possible to define a maximum permissible scan time in order to be able to carry out the scan e.g. while holding one's breath. Equally, it is possible to define a maximum permissible pitch in order e.g. to limit the artifact intensity. Finally, it is possible to define a minimum pitch in order e.g. not to fall below a specific temporal resolution.

These user-defined limits either cannot be exceeded at all, or can only be exceeded after confirmation of an indication in this respect which is displayed on the display unit 9 by the computer, [through] by corresponding actuation of the keyboard 12.

Instead of exceeding the technical or user-defined limits, the computer 8 can [also] perform a change in operational parameters other than those (I, T) mentioned above, in order to enable a desired scan. Thus, [by way of] as an example, it is possible to change the *mAs* product contributing to the reconstructed sectional image, the effective [layer] slice thickness, the focus

size, the rotation time or the waiting time that influences the thermal loading capacity and hence the maximum permissible scan time, before the scan. Such changes can again be effected automatically or [are] performed by the computer 8 only after confirmation of an indication in this respect which is displayed on the display unit 9 by the computer 8, [through] by corresponding actuation of the keyboard 12.

It is also possible to change a [plurality] number of operating parameters in order to enable a desired scan. In this case, [scheme] protocols concerning the order in which the individual operational parameters are to be changed are stored in the computer 8, for example in the [already mentioned] memory provided for the technical limit values of the CT device. As an alternative, said order may be influenced or determined by the user by means of the keyboard 12.

Thus, it may be expedient, for example[, that,] in the event of excessively high loading, for the computer 8 [firstly reduces] to first reduce the tube current *I* [whilst] while simultaneously lengthening the scan time. If the scan time reaches a maximum permissible scan time before the loading falls below the permissible thermal loading of the X-ray source 1, then the computer 8, in order to enable the scan, switches e.g. to a larger focus of the X-ray source 1. If this still does not suffice to bring about a permissible operating state, the computer 8 may additionally reduce e.g. the *mAs* product.

Figure 3 diagrammatically illustrates the described method of operation of a CT device according to the invention in the form of a flow diagram, to be precise for the case where changes of operational parameters require enabling by the user. In this case, O. parameters denotes operational parameters in Figure 3. The term "permissible limit" encompasses both technical limits of the CT device and limit values defined by the user within these limits.

The stepwise procedure already described above is described, according to which, in the case of a limit being exceeded, firstly a change is made to the operational parameters tube current I and scan time T under the condition mAs = const., and, if this change does not suffice, other operational parameters are optimized [whilst] <u>while</u> taking account of the limits. If a useable combination of operational parameters cannot be realized in this way, then it becomes clear from Figure 3 that it is then incumbent upon the user to manually adapt operational parameters in order to bring about a situation which enables a scan to be carried out.

The method of operation of the CT device according to the invention was described above for the case where a single scan is to be effected. However, it applies equally to cases in which a sequence of scans is to be performed, whether with the scans directly succeeding one another, or with the scans being separated from one another by time intervals.

The invention, though this is particularly advantageous, is not restricted to [application as in the case of] the [described] exemplary embodiment [in] <u>of</u> spiral scans on the basis of a reconstruction algorithm in which the [layer] <u>slice</u> sensitivity profile of a reconstructed sectional image does not depend significantly on the pitch, whereas the *mAs* product contributing to the sectional image is dependent on the pitch. The invention [can] also <u>can</u> be employed in conjunction with any other [types] <u>type</u> of scan which [do] <u>does</u> not involve spiral scans, [that is to say,] for example, individual planar scans or sequences of planar scans (sequential scan).

In the [case of the] exemplary embodiment [described, what is involved is] a CT device with a detector having a single linear array of detector elements <u>is described</u>. However, the invention is not restricted to CT devices with such detectors, but rather also encompasses CT devices with detectors having a [plurality] <u>number</u> of linear arrays of detector elements (multi-linear-array detectors) and also CT devices with detectors

having a multiplicity of detector elements arranged in a [matrix-like manner] (matrix array detector).

The invention was explained above using the example of a third-generation CT device. However, it can also be employed in fourth-generation CT devices which, instead of an arcuate detector that can be adjusted with the X-ray source about the system axis, has a stationary ring of detector elements.

The invention can be used both in the medical field and in [the] non-medical [field] <u>fields</u>.

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Description

Computer tomography (CT) device

The invention relates to a CT device having adjustable operational parameters, which has a control unit, wherein means for preselecting a combination of operational parameters for an examination to be carried out are provided.

During examinations with computer tomographs, it can happen that examinations cannot be carried out with a combination of operational parameters that is desired by the user, on account of technical or user-defined limitations of the permissible values of the operational parameters of the CT device. In particular, the thermal loading capacity of the X-ray source - generally embodied as an X-ray tube - of the CT device has a limiting effect on specific operational parameters (e.g. scan time, i.e. that period of time during which an object under examination is irradiated with X-rays in order to carry out an examination, scan length, i.e. that extent of the object under examination in the direction of the system axis over which an object under examination is scanned with X-rays in order to carry out an examination, tube current, tube voltage, etc.).

EP-A-0 809 422 describes a method for establishing and/or correcting exposure errors in X-ray radiographs, in which, during the recording of an X-ray image, a check is made to determine whether the actual exposure rate corresponds to a predicted exposure rate. If this is not the case, the recording is terminated or suitable recording parameters are corrected with the aim of achieving a correct exposure.

The invention is based on the object of designing a CT device of the type mentioned in the introduction in such a way that a user is provided with a control aid for those examinations for which the user has set a combination of operational parameters which does not lie at least within the technical limits with regard to the individual operational parameters.

According to the invention, this object is achieved by means of a CT device having the features of patent claim 1.

Thus, the CT device according to the invention affords a possibility of resolving conflicts for those combinations of operational parameters which do not lie within the technical limits of the CT device and/or within user-defined limit values (patent claim 8), with the consequence that the corresponding examination could not actually be carried out. This is because in the case of the CT device according to the invention, a value is determined for at least one operational parameter of the preselected combination, which value has been changed such that, on the one hand, the image quality, in particular the image noise, is maintained as far as possible in comparison with the initially set combination of operational parameters and, on the other hand, the CT device is operated within the permissible technical or user-defined limits. The respective user is thus enabled by a control aid to carry out an examination which ultimately at least essentially corresponds to the examination that he originally intended, but can be carried out without technical limits of the CT device and/or user-defined limit values being exceeded, exceed in this case not being intended to be understood in the literal sense but rather to the effect that a limit value is transgressed, that is to say an upper limit value is exceeded or a lower limit value is undershot.

It goes without saying that the changes to the operational parameters which are specified by the control unit are possible only within the technical limits of the CT device. Technical limits include, inter alia: maximum and minimum tube current that can be set, maximum and minimum possible scan time, maximum and minimum pitch that can be set, i.e. the advance in the direction of the system axis per revolution of the radiation source relative to the collimated width of a linear array of detector elements of the detector (collimated layer thickness), etc.

In order to bring about a combination of operational parameters which does not represent an impermissible operating state, the

control unit can change one or a plurality of operational parameters of the chosen combination of operational parameters.

The changes to the operational parameters which are specified by the control unit can either be set automatically (with or without corresponding information of the user) or be presented to the user as a proposal, in the latter case the actual setting of a deviating operational parameter being effected only in response to corresponding enabling by the user. The first-mentioned variant, whether with or without information of the user, is advantageous when marginal changes in one or a plurality of operational parameters are sufficient. By contrast, if relatively large changes are necessary, in particular those which have an effect in the sense of impairing the expected image quality, then the last-mentioned variant, which provides for enabling by the user, is advantageous. In this case, it may be provided that the CT device has means which decide whether an automatic change can be effected or enabling by the user is required, depending on the operational parameter affected in each case and on the extent of the required change, for example on the basis of a table which contains the corresponding information and is stored in the CT device.

In accordance with one particularly preferred variant of the invention, the CT device according to the invention is provided for carrying out spiral scans in which an X-ray source rotates around an object under examination and, at the same time, a translational relative movement is effected between the object under examination, on the one hand, and the X-ray source and also a detector, on the other hand, wherein the spiral scan is carried out during a scan time during which the X-ray source is operated with a tube current, and wherein the control unit, in the case of an

impermissible preselected combination of operational parameters, in order to avoid an impermissible operating state, specifies a value for the at least one operational parameter

which results using the value specified for the at least one operational parameter, the product of tube current and scan time (mAs product) is not significantly reduced by comparison with the preselected combination of operational parameters.

It is ensured that the *mAs* product used for carrying out the envisaged examination is not significantly reduced by the change in the operational parameters. Since the *mAs* product, which contributes to a reconstructed sectional image (CT image), is crucial to the image noise and hence the image quality (the image noise increases as the *mAs* product decreases), it is ensured that despite the changed operational parameters, no considerable change in the image quality occurs.

Since, for the 180LI or 360LI interpolation which is typically used in the reconstruction of sectional images from spiral scans and is described in the literature, it is difficult to comply with this condition - in these types of interpolation, the layer sensitivity profile is dependent on the pitch, while the *mAs* product is independent of the pitch -, one embodiment of the invention provides for an electronic computing device for the reconstruction of sectional images, to be provided which reconstructs the sectional images in such a way that the layer sensitivity profile of a reconstructed sectional image is at least essentially independent of the pitch, while the *mAs* product serving for obtaining the data on which a sectional image is in each case based depends on the pitch. In this case, the *mAs* product, which contributes to a reconstructed sectional image, is proportional to

the product of tube current and scan time, with the consequence that the image noise only depends on the product of tube current and scan time if no otheroperational parameters are changed. The requirement that no reduction in the image quality is supposed to occur as a result

of the specified changes to operational parameters can then be met, in accordance with one variant of the invention, by the fact that the product of tube current and scan time in the case of the operational parameters prescribed by the control unit is equal to the product of tube current and scan time in the case of the desired combination of operational parameters. This procedure encounters its limits, however, in the case of large pitch values p (guide value $p > 1.5 * n$, where n=1 in the case of a CT device with a detector system having a single linear array of detector elements, and corresponds to the number of simultaneously recorded layers in the case of a CT device with a detector system having a plurality of linear arrays of detector elements), since image artifacts increase appreciably in that case.

As already mentioned, within the technical limits of the device, in accordance with patent claim 8, the user can additionally set upper or lower limit values for operational parameters within which the changes to the operational parameters which are specified by the control unit must range. Thus, it is possible to define e.g. a maximum permissible scan time in order to be able to carry out a scan, i.e. an examination, e.g. within a time of holding one's breath. Equally it is possible to define a maximum permissible pitch in order e.g. to limit the intensity of the artifacts in the reconstructed sectional images. Furthermore, it is possible to define a minimum pitch in order, for example, to prevent a specific temporal resolution from being undershot.

In accordance with one variant of the invention, operational parameters can be changed whilst taking account of an optimization aim, in which case, if a plurality of optimization aims are present, it is possible to prescribe a rank order of the optimization

aims. The optimization aims provided may be, for example, minimum scan time, maximum spatial resolution, maximum temporal resolution, maximum scan length.

If, on the basis of the preselected combination of operational parameters, whilst complying with the limit values, it is not possible to determine a combination of operational parameters which represents a permissible operating state, it is unavoidable for at least one limit value to be exceeded. For this case, one variant of the invention provides for the control unit to offer for selection at least one combination of operational parameters which, with at least one limit value not being complied with, is approximated to the respective preselected combination of operational parameters without an impermissible operating state being present. In this connection, it may be provided that the control unit offers a plurality of combinations of operational parameters which are based on various optimization aims, with the result that the user can choose a permissible combination of operational parameters for which one or a plurality of limit values is or are exceeded in the sense of an optimization aim corresponding to the respective case of examination. Embodiments of the invention may provide for the control unit to automatically set a value of the corresponding operational parameter which exceeds a limit value, if appropriate with the user being informed, and to carry out the envisaged examination, or to inform the user about a value of the corresponding operational parameter which exceeds a limit value and to carry out the envisaged examination only when the user enables the performance of the envisaged examination. This last is expedient principally in those cases in which not complying with the limit value might lead to a reduction in the image quality compared with the image quality which would be achieved in the case of the preselected combination of operational parameters.

One variant of the invention provides for the control

unit to offer combinations of operational parameters for successive examinations of the same object under examination whilst taking account of various optimization aims. It is then possible, for example, successively

to carry out firstly an examination with maximum spatial resolution and then an examination with maximum temporal resolution.

A further variant of the invention provides for means for inputting a rank order of the operational parameters are provided, and the control unit complies with the rank order of the operational parameters in the event of operational parameters being changed to values which deviate from values of a preselected combination of operational parameters, i.e. an attempt is made to realize a permissible combination of operational parameters first of all by changing the operational parameter which is in first place in the rank order. If this is unsuccessful, then the control unit seeks to bring about a permissible combination of operational parameters by changing the operational parameter which is in second place in the rank order, etc. It is thus possible to prescribe a rank order which ensures that the values of specific operational parameters deemed by a user to be particularly significant for the respective examination to be carried out are changed only when this is unavoidable, by the corresponding operational parameters being placed as far down as possible on the priority list.

The invention is explained by way of example below with reference to the accompanying drawings, in which:

Figure 1 shows a CT device according to the invention in a diagrammatic illustration,

Figure 2 shows a diagram illustrating the relationship between tube current and scan time, and

Figure 3 shows a flow diagram illustrating the function of the CT device in accordance with

Figure 1.

A CT device according to the invention is illustrated roughly diagrammatically in Figure 1, said device having an X-ray source 1, e.g. an

X-ray tube, with a focus 2, from which emerges a fan-shaped X-ray beam 3 which is inserted through a diaphragm (not illustrated), penetrates through an object 4 under examination, for example a patient, and impinges on an arcuate detector 5. The latter comprises a detector linear array formed by a row of detector elements. The X-ray source 1 and the detector 5 form a measurement system which can be rotated about a system axis 6 which is at right angles to the plane of the drawing in Figure 1, with the result that the object 4 under examination is irradiated under different projection angles α. The detector elements of the detector 5 produce output signals in this case and from said output signals a data acquisition system 7 forms measured values which are referred to hereinafter as measured projections and are fed to a computer 8.

A larger volume of the object 4 under examination can be scanned by the measurement system 1, 5 performing a spiral scan of the desired volume. In this case, a relative movement takes place between the measurement arrangement comprising X-ray source 1 and detector 5, on the one hand, and the object 4 under examination, on the other hand, in the direction of the system axis 6, which thus simultaneously represents the longitudinal axis of the spiral scan, preferably by displacement of a mounting device 10, provided for receiving the object 4 under examination, in the direction of the system axis 6.

A keyboard 12, which enables the CT device to be controlled, is connected to the computer 8, which, in the case of the exemplary embodiment described, is at the same time a control unit and performs the control of the CT device (it is also possible to provide a

separate computer as a control unit).

The computer 8 also serves, in particular, to set the tube current, and hence the output power, of the X-ray source 1 supplied by a generator circuit 11.

The irradiation under different projection angles α is effected with the aim of obtaining measured projections. To that end, the X-ray source 1 irradiates the object 4 under examination with the X-ray beam 3 emerging from successive positions of the focus 2 which lie on the spiral track described by the focus 2, each position of the focus 2 being assigned to a projection angle and to a z-position on a z-axis corresponding to the system axis 6.

On account of the spiral scan, at most one measured projection can exist with respect to an image plane running at right angles to the system axis 6, which measured projection was recorded with a position of the focus 2 lying in this image plane. In order nevertheless to be able to calculate a sectional image of that layer of the object 4 under examination which is associated with the respective image plane, calculated projections lying in the image plane thus have to be obtained by suitable interpolation methods from measured projections recorded in the vicinity of the image plane, and, as in the case of measured projections, each calculated projection is assigned to a projection angle α and to a z-position with respect to the system axis 6.

From the projections associated with a respectively desired image plane, the computer 8 reconstructs a sectional image according to reconstruction algorithms known per se and represents them on a display unit 9, e.g. a monitor.

The keyboard 12 can be used to set operational parameters of the CT device, e.g.

- Scan time,
- *mAs* product per sectional image, i.e. the product of that time in which the data on which

the sectional image is based were obtained and the tube current I set during this time

- effective layer thickness, also referred to as reconstructed layer thickness, i.e. the extent measured

in the direction of the system axis - of that region of the object under examination which contributes to the reconstructed image. By way of example, the half-value width of the so-called layer sensitivity profile serves as a measure.

- collimated layer thickness, i.e. the extent - set by means of corresponding ray diaphragms and measured in the direction of the system axis - of an X-ray beam impinging on a linear array of detector elements,
- rotation time, i.e. the time that elapses during a complete revolution (360°) of the X-ray source,
- pitch (only for spiral scans),
- scan length,
- focus size, i.e. dimensions of the focal spot of the X-ray source from which the X-rays emerge.

If a user uses the keyboard 12 to input a combination of operational parameters which is intended to form the basis for the performance of an examination, then this initially represents only a preliminary selection, because the computer 8 checks this combination of operational parameters before the performance of the examination to determine whether said combination might lead to an impermissible operating state of the CT device. To that end, the computer 8 on the one hand considers the technical limits of the CT device, and on the other hand it considers user-defined limits for individual operational parameters which can likewise be input by means of the keyboard 12. Values with respect to the technical limits of the CT device are stored in a memory associated with the computer 8.

If the computer 8 ascertains that a combination of

operational parameters preselected using the keyboard 12 might lead to an impermissible operating state, then it determines, for at least one operational parameter, a value which deviates from the preselected combination of operational parameters and for which

the planned examination can be carried out whilst avoiding an impermissible operating state without a significant reduction in the image quality by comparison with the preselected combination of operational parameters.

In this connection, communication takes place between the user and the CT device by means of the keyboard 12 and the display unit 9, a combination of operational parameters with which the CT device finally performs the planned examination being defined during said communication. An additional display unit may also possibly be provided for the purposes of communication, with the consequence that the display unit 9 is then reserved solely for displaying the reconstructed sectional images.

The way in which this communication proceeds is explained below using the example of the two operational parameters tube current I and scan time T.

The thermal loading capacity of the X-ray source 1 can be described by the two operational parameters tube current I and scan time T. Depending on the thermal preloading and, if appropriate, depending on the focus size and tube voltage of the X-ray source 1 selected via the keyboard, the present thermal loading capacity varies, which is determined by the computer 8 or a particular load computer, assigned to the X-ray source and communicating with the computer 8, taking account of the thermal preloading. The present thermal loading capacity is represented as a function of the tube current I and the scan time T as dashed curve 1 in Figure 2 qualitatively on the basis of a specific preloading of the X-ray source 1. All scans with combinations of the operational parameters I and T which lie below the curve 1 can be carried out, whereas

scans with combinations of the operational parameters *I* and *T* above the curve 1 would exceed the thermal loading capacity of the X-ray source 1. They thus lead to impermissible operating

states for which reason they cannot, therefore, be performed and are blocked by the computer 8.

Generally, there is no mathematically simple relationship between the operational parameters I and T for a given loading capacity, in particular $I \cdot T = \text{const.}$ generally does not hold true. Thus, by way of example, if the scan time is doubled for a specific thermal loading capacity, then the tube current generally need not be halved, but rather be reduced only by e.g. 20%.

The image quality, i.e. the image noise, of the sectional images generated is essentially determined by the *mAs* product, which contributes to a reconstructed sectional image. By changing the *mAs* product, with otherwise unchanged operational parameters and parameters of the image reconstruction algorithm, the noise in the sectional image is changed, while the same *mAs* product yields at least essentially the same noise and thus approximately the same image quality.

The computer 8 of the CT device according to the invention calculates, on the basis of the data obtained during a spiral scan, sectional images by means of an image reconstruction algorithm in which the layer sensitivity profile of a reconstructed sectional image does not depend significantly on the pitch, whereas the *mAs* product contributing to the sectional image is dependent on the pitch. In such an image reconstruction algorithm, the procedure is such that, with respect to each projection angle, all the measured values which are associated with this projection angle and lie within a maximum distance from the image plane are incorporated in the reconstruction in a weighted manner according to their spatial distance in the direction of the longitudinal axis of the spiral scanning from the

image plane in accordance with a weighting function, and that the weighting function is chosen such that the layer thickness is at least essentially independent of the pitch.

Consequently, the following relationship holds true:

$$I \propto mAs \cdot p = \frac{mAs \cdot L \cdot ROT}{coll \cdot T} \qquad \text{(Equation 1)}$$

In this case:

I: denotes the tube current
P: denotes the pitch
L: denotes the scan length
ROT: denotes the rotation time
coll: denotes the collimated layer thickness
T: denotes the scan type

It becomes clear from Equation 1 that the *mAs* product contributing to a reconstructed sectional image is proportional to the product $I \cdot T$ of tube current and scan time. Thus, in the reconstruction algorithm employed, the image quality only depends on the product $I \cdot T$ if the other parameters (collimated *coll* and reconstructed layer thickness, scan length *L* and rotation time *ROT*) are not changed. However, image artifacts may increase appreciably in the case of large values of the pitch *p*.

Figure 2 additionally illustrates a solid curve - designated by curve 2 - of constant image quality, for which $I \cdot T$ = const. holds true, with the consequence that, for a sectional image generated with values corresponding to a point on the curve 2, a constant mAs product which is independent of the position of the point on the curve 2 is used, thereby achieving a constant image noise and hence a constant image quality.

Generally, one part of the curve 2 lies above the permissible thermal loading of the X-ray source 1 in

accordance with curve 1, and another part lies below it. If we consider, by way of example, a scan - designated by scan 1 - with a combination of the

operational parameters I and T above curve 1, this scan would be impermissible on account of excessively high thermal loading of the X-ray source 1. The properties of the abovementioned reconstruction algorithm now make it possible to change the combination of the operational parameters I and T, without any losses in image quality, to the extent that the permissible thermal loading in accordance with curve 1 is no longer exceeded. The corresponding combination of the operational parameters I and T is designated by scan 2. In the case illustrated, the tube current I is reduced and the scan time T is simultaneously lengthened, the operational parameters for scan 2 being chosen whilst taking account of curve 1 such that they are as close as possible to the originally preselected operational parameters in accordance with scan 1. The reduction in the pitch p accompanying the lengthened scan time T does not lead to a significant change in the layer sensitivity profile on account of the reconstruction algorithm used.

The changing of the operational parameters to the effect that the loading capacity of the CT system is no longer exceeded, without this being associated with losses of image quality, can either be carried out automatically by the computer 8 (with or without a corresponding indication to the user displayed on the display unit 9 by the computer 8) or be presented to the user as a proposal by the computer 8, in which case the computer 8 displays a possible indication or a proposal, in the case of the exemplary embodiment described, on the display unit 9 and a proposal can be adopted by the user through corresponding actuation of the keyboard 12 as enable means.

Changes in the operational parameters are possible only within the technical limits of the device. Technical

limits may include, in addition to the thermal loading capacity of the X-ray source, inter alia: maximum and minimum tube current that can be set, maximum and minimum pitch that can be set, maximum and minimum scan time that can be set.

In the case of the reconstruction algorithms known as 180°LI and 360°LI interpolation algorithms, the procedure described with regard to the setting of the tube current *I* and the scan time *T* is not possible since, in the case of these algorithms, the layer sensitivity profile is dependent on the pitch *p*, whereas the *mAs* product is independent of the pitch *p*.

Within the technical limits of the CT device, by means of the keyboard 12, the user can additionally set user-defined limit values with regard to the operational parameters within which a change in the respective operational parameter is only possible in that case: thus, by way of example, it is possible to define a maximum permissible scan time in order to be able to carry out the scan e.g. while holding one's breath. Equally, it is possible to define a maximum permissible pitch in order e.g. to limit the artifact intensity. Finally, it is possible to define a minimum pitch in order e.g. not to fall below a specific temporal resolution.

These user-defined limits either cannot be exceeded at all, or can only be exceeded after confirmation of an indication in this respect which is displayed on the display unit 9 by the computer, through corresponding actuation of the keyboard 12.

Instead of exceeding the technical or user-defined limits, the computer 8 can also perform a change in operational parameters other than those (*I*, *T*) mentioned above, in order to enable a desired scan. Thus, by way of example, it is possible to change the *mAs* product contributing to the reconstructed sectional image, the effective layer thickness, the focus size, the rotation time or the waiting time that influences the thermal loading capacity and hence the maximum

permissible scan time, before the scan. Such changes can again be effected automatically or are performed by the computer 8 only after confirmation of an indication in this respect which is displayed on the

display unit 9 by the computer, through corresponding actuation of the keyboard 12.

It is also possible to change a plurality of operating parameters in order to enable a desired scan. In this case, schemes concerning the order in which the individual operational parameters are to be changed are stored in the computer 8, for example in the already mentioned memory provided for the technical limit values of the CT device. As an alternative, said order may be influenced or determined by the user by means of the keyboard 12.

Thus, it may be expedient, for example, that, in the event of excessively high loading, the computer 8 firstly reduces the tube current *I* whilst simultaneously lengthening the scan time. If the scan time reaches a maximum permissible scan time before the loading falls below the permissible thermal loading of the X-ray source 1, then the computer 8, in order to enable the scan, switches e.g. to a larger focus of the X-ray source 1. If this still does not suffice to bring about a permissible operating state, the computer 8 may additionally reduce e.g. the *mAs* product.

Figure 3 diagrammatically illustrates the described method of operation of a CT device according to the invention in the form of a flow diagram, to be precise for the case where changes of operational parameters require enabling by the user. In this case, O. parameters denotes operational parameters in Figure 3. The term "permissible limit" encompasses both technical limits of the CT device and limit values defined by the user within these limits.

The stepwise procedure already described above is described, according to which, in the case of a limit

being exceeded, firstly a change is made to the operational parameters tube current I and scan time T under the condition mAs = const., and, if this change does not suffice, other

operational parameters are optimized whilst taking account of the limits. If a useable combination of operational parameters cannot be realized in this way, then it becomes clear from Figure 3 that it is then incumbent upon the user to manually adapt operational parameters in order to bring about a situation which enables a scan to be carried out.

The method of operation of the CT device according to the invention was described above for the case where a single scan is to be effected. However, it applies equally to cases in which a sequence of scans is to be performed, whether with the scans directly succeeding one another, or with the scans being separated from one another by time intervals.

The invention, though this is particularly advantageous, is not restricted to application as in the case of the described exemplary embodiment in spiral scans on the basis of a reconstruction algorithm in which the layer sensitivity profile of a reconstructed sectional image does not depend significantly on the pitch, whereas the *mAs* product contributing to the sectional image is dependent on the pitch. The invention can also be employed in conjunction with any other types of scan which do not involve spiral scans, that is to say, for example, individual planar scans or sequences of planar scans (sequential scan).

In the case of the exemplary embodiment described, what is involved is a CT device with a detector having a single linear array of detector elements. However, the invention is not restricted to CT devices with such detectors, but rather also encompasses CT devices with detectors having a plurality of linear arrays of detector elements (multi-linear-array detectors) and also CT devices with detectors having a multiplicity of

detector elements arranged in a matrix-like manner (matrix array detector).

The invention was explained above using the example of a third-generation CT device. However, it can also be employed in fourth-generation CT devices which, instead of an arcuate detector that can be adjusted with the X-ray source about the system axis, has a stationary ring of detector elements.

The invention can be used both in the medical field and in the non-medical field.

Patent claims

1. A computer tomography (CT) device having adjustable operational parameters, which has a control unit and means for preselecting a combination of operational parameters for an examination to be carried out, wherein a control unit, for the case where a combination of operational parameters which might lead to an impermissible operating state is preselected for an examination to be carried out, determines, for at least one operational parameter, a value which deviates from the preselected combination of operational parameters and for which the envisaged examination can be carried out in a manner avoiding the impermissible operating state without a significant reduction in the image quality by comparison with the preselected combination of operational parameters.

2. The CT device as claimed in claim 1, in which the control unit automatically sets the value of the at least one operational parameter which is required for avoiding an impermissible operating state, and carries out the envisaged examination.

3. The CT device as claimed in claim 2, in which the control unit informs a user about each value of an operational parameter which is automatically set in a manner deviating from the preselected combination of operational parameters.

4. The CT device as claimed in claim 1, in which the control unit informs a user about the value required for avoiding an impermissible operating state and carries out the envisaged examination with this value if the user enables the performance of the envisaged examination using

Patent claims

1. A computer tomography (CT) device having adjustable operational parameters (I, T), which has a control unit (8) and means (12) for preselecting a combination of operational parameters (I, T) for an examination to be carried out, wherein a control unit (8), for the case where a combination of operational parameters (I, T) which might lead to an impermissible operating state is preselected for an examination to be carried out, determines, for at least one operational parameter (I, T), a value which deviates from the preselected combination of operational parameters (I, T) and for which the envisaged examination can be carried out in a manner avoiding the impermissible operating state without a significant reduction in the image quality by comparison with the preselected combination of operational parameters (I, T).

2. The CT device as claimed in claim 1, in which the control unit (8) automatically sets the value of the at least one operational parameter (I, T) which is required for avoiding an impermissible operating state, and carries out the envisaged examination.

3. The CT device as claimed in claim 2, in which the control unit (8) informs a user about each value of an operational parameter (I, T) which is automatically set in a manner deviating from the preselected combination of operational parameters (I, T).

4. The CT device as claimed in claim 1, in which the

control unit (8) informs a user about the value required for avoiding an impermissible operating state and carries out the envisaged examination with this value if the user enables the performance of the envisaged examination using enabling means (12).

5. The CT device as claimed in one of claims 1 to 4, which is provided for carrying out spiral scans in which an X-ray source (1) rotates around an object (4) under examination and, at the same time, a translational relative movement is effected between

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the object (4) under examination, on the one hand, and the X-ray source (1) and also a detector (5), on the other hand, wherein the spiral scan is carried out with a defined effective layer thickness during a scan time (T) during which the X-ray source (1) is operated with a tube current (I), and wherein the control unit (8), in the case of an impermissible preselected combination of operational parameters (I, T), in order to avoid an impermissible operating state, specifies a value for the at least one operational parameter (I, T) such that, in the case of the combination of operational parameters (I, T) which results using the value specified for the at least one operational parameter (I, T), the *mAs* product contributing to a sectional image of the defined effective layer thickness is not significantly reduced by comparison with the preselected combination of operational parameters (I, T).

6. The CT device as claimed in claim 5, which has an electronic computing device for the reconstruction of sectional images, which reconstructs the sectional images in such a way that the layer sensitivity profile of a reconstructed sectional image is at least essentially independent of the pitch, while the *mAs* product serving for obtaining the data on which a sectional image is in each case based depends on the pitch.

7. The CT device as claimed in claim 6, in which the product of tube current (I) and scan time (T) in the case of the operational parameters prescribed by the control unit (8) is equal to the product of tube current (I) and scan time (T) in the case of the desired combination of operational parameters.

8. The CT device as claimed in one of claims 1 to 7, in which means (12) for inputting permissible upper and/or lower limit values for at least one operational parameter of the following group of operational parameters are provided:

- maximum permissible scan time
- minimum and maximum *mAs* product per sectional image
- minimum and maximum effective layer thickness
- minimum and maximum collimated layer thickness
- minimum and maximum rotation time
- minimum and maximum pitch (only for spiral scans)
- minimum and maximum scan length
- minimum and maximum waiting time before the scan
- focus size

9. The CT device as claimed in claim 8, in which the control unit (I, T) optimizes the operational parameters (I, T) of a preselected combination of operational parameters (I, T) whilst taking account of a possible upper and/or lower limit value in the sense of an optimization aim.

10. The CT device as claimed in claim 9, which has, as optimization aim, at least one optimization aim from the following group:
    - minimum scan time,
    - maximum spatial resolution,
    - maximum temporal resolution,
    - maximum scan length.

11. The CT device as claimed in claim 9 or 10, in which means (12) for inputting a rank order of the optimization aims are provided.

12. The CT device as claimed in one of claims 8 to 11, in which the control unit (8), for the case where it is unavoidable not to comply with a limit value, offers for selection at least one

combination of operational parameters (I, T)which is approximated to the respective preselected combination of operational parameters (I, T) without an impermissible operating state being present.

13. The CT device as claimed in claim 12, in which the control unit (8) offers a plurality of combinations of operational parameters (I, T) which are based on various optimization aims.

14. The CT device as claimed in claim 12 or 13, in which the control unit (8) automatically sets a value of the corresponding operational parameter (I, T) which does not comply with a limit value, and carries out the envisaged examination.

15. The CT device as claimed in claim 14, in which the control unit (8) informs a user about each automatically set value of an operational parameter (I, T) which does not comply with a limit value.

16. The CT device as claimed in one of claims 11 to 13, in which the control unit (8) informs a user about a value of the corresponding operational parameter (I, T) which does not comply with a limit value, and carries out the envisaged examination with this value if the user enables the performance of the envisaged examination using enabling means (12).

17. The CT device as claimed in one of claims 9 to 16, in which the control unit (8) offers combinations of operational parameters (I, T) for successive examinations of the same object (4) under examination whilst taking account of various optimization aims.

18. The CT device as claimed in claim 1 or 17, in which means (12) for inputting a rank order of the operational parameters (I, T) are provided, and

the control unit (8) complies with the rank order of the operational parameters (I, t) in the event of operational parameters (I, T) being changed to values which deviate from values of a preselective combination of operational parameters (I, T).

10/009859

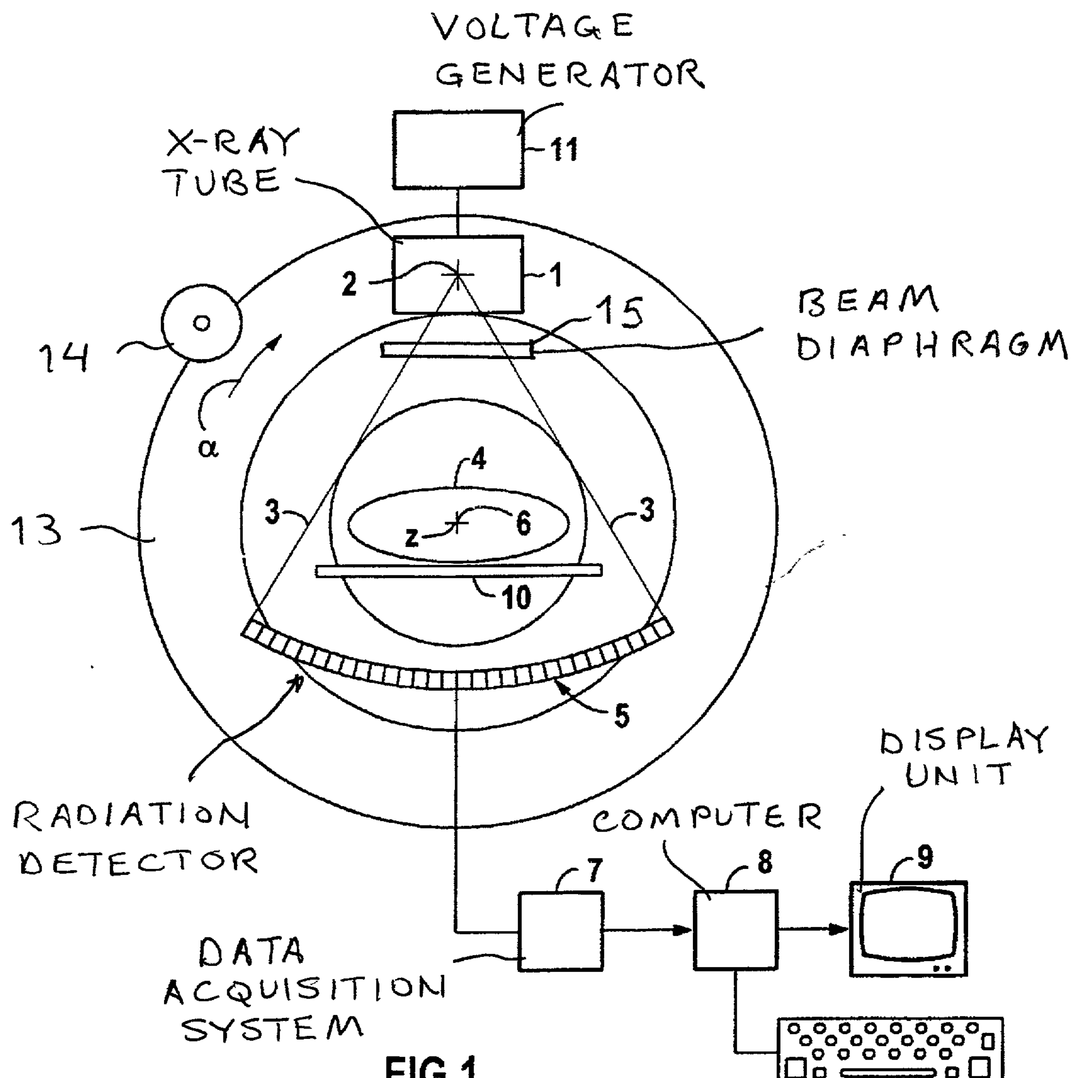

FIG 1

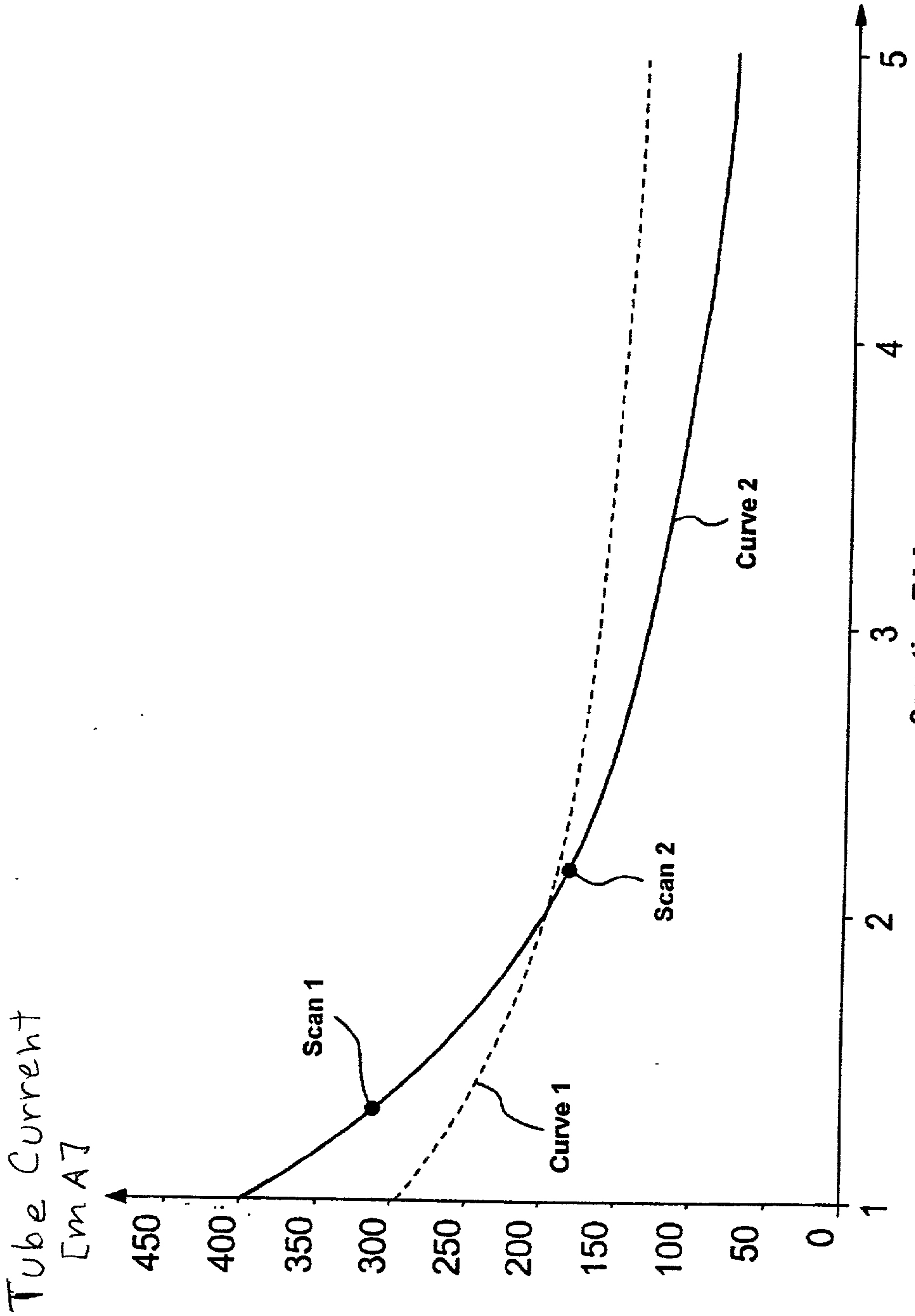
Tube Current
[mA]
450
400
350
300
250
200
150
100
50
0
1
2
3
4
5
Scan time T [s]
Scan 1
Scan 2
Curve 1
Curve 2

FIG 2

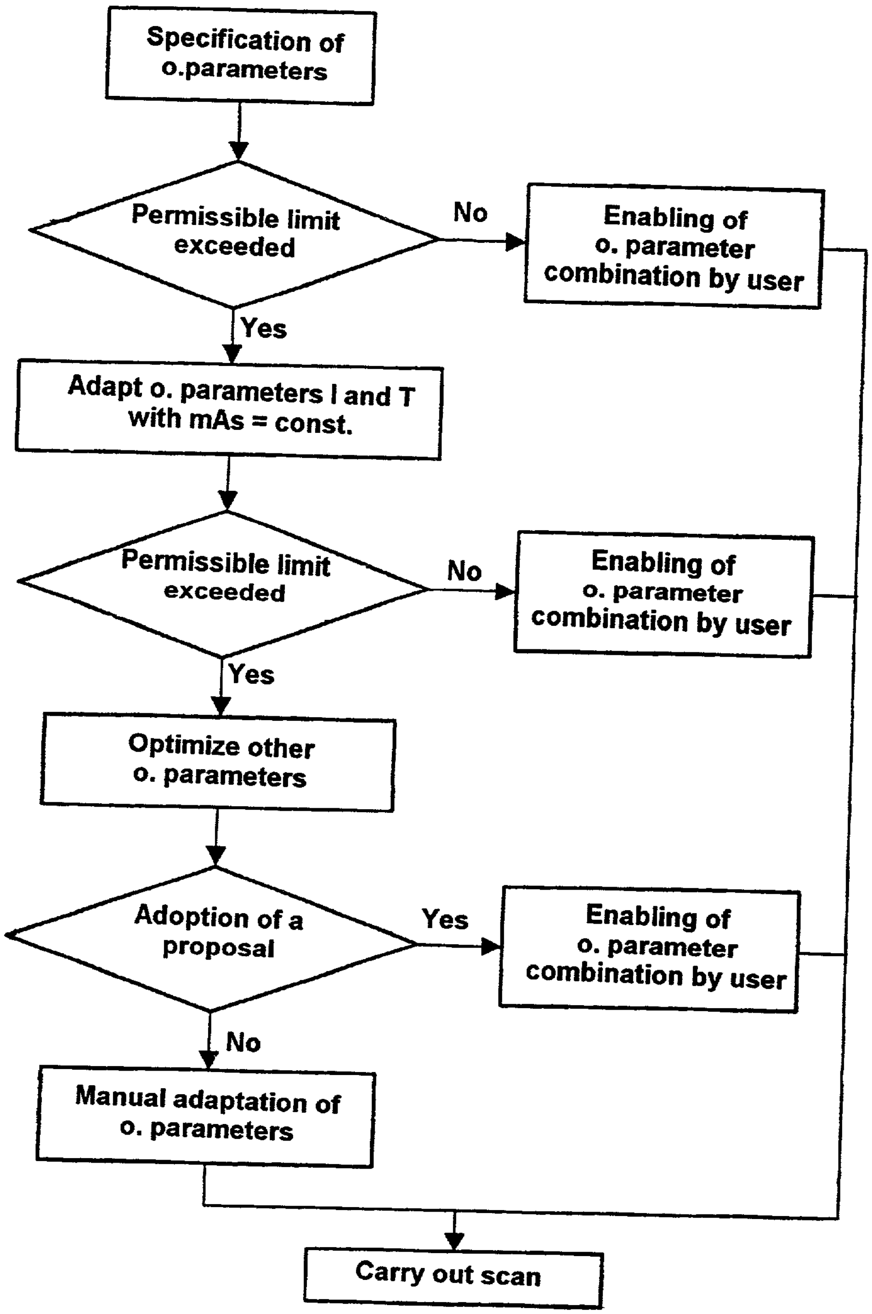
Specification of o.parameters
Permissible limit exceeded
No
Enabling of o. parameter combination by user
Yes
Adapt o. parameters I and T with mAs = const.
Permissible limit exceeded
No
Enabling of o. parameter combination by user
Yes
Optimize other o. parameters
Adoption of a proposal
Yes
Enabling of o. parameter combination by user
No
Manual adaptation of o. parameters
Carry out scan

FIG 3

Declaration and Power of Attorney For Patent Application
Erklärung Für Patentanmeldungen Mit Vollmacht
German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

As a below named inventor, I hereby declare that:

dass mein Wohnsitz, meine Postanschrift, und meine Staatsangehörigkeit den im Nachstehenden nach meinem Namen aufgeführten Angaben entsprechen,

My residence, post office address and citizenship are as stated below next to my name,

dass ich, nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent beantragt wird für die Erfindung mit dem Titel:

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

Computertomogaphie(CT)-Geraet

Computer tomography

deren Beschreibung

(zutreffendes ankreuzen)
☐ hier beigefügt ist.
☒ am 25.04.2000 als
PCT internationale Anmeldung
PCT Anmeldungsnummer PCT/DE00/01276
eingereicht wurde und am ________
abgeändert wurde (falls tatsächlich abgeändert).

the specification of which

(check one)
☐ is attached hereto.
☒ was filed on 25.04.2000 as
PCT international application
PCT Application No. PCT/DE00/01276
and was amended on ________
(if applicable)

Ich bestätige hiermit, dass ich den Inhalt der obigen Patentanmeldung einschliesslich der Ansprüche durchgesehen und verstanden habe, die eventuell durch einen Zusatzantrag wie oben erwähnt abgeändert wurde.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims as amended by any amendment referred to above.

Ich erkenne meine Pflicht zur Offenbarung irgendwelcher Informationen, die für die Prüfung der vorliegenden Anmeldung in Einklang mit Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) von Wichtigkeit sind, an.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäss Abschnitt 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 119 aller unten angegebenen Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde, und habe auch alle Auslandsanmeldungen für ein Patent oder eine Erfindersurkunde nachstehend gekennzeichnet, die ein Anmeldedatum haben, das vor dem Anmeldedatum der Anmeldung liegt, für die Priorität beansprucht wird.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

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Prior foreign appplications
Priorität beansprucht

Priority Claimed

19919423.8	DE	28.04.1999	☒	☐
(Number)	(Country)	(Day Month Year Filed)	Yes	No
(Nummer)	(Land)	(Tag Monat Jahr eingereicht)	Ja	Nein
			☐	☐
(Number)	- (Country)	(Day Month Year Filed)	Yes	No
(Nummer)	(Land)	(Tag Monat Jahr eingereicht)	Ja	Nein
			☐	☐
(Number)	-(Country)	(Day Month Year Filed)	Yes	No
(Nummer)	(Land)	(Tag Monat Jahr eingereicht)	Ja	Nein

Ich beanspruche hiermit gemäss Absatz 35 der Zivilprozessordnung der Vereinigten Staaten, Paragraph 120, den Vorzug aller unten aufgeführten Anmeldungen und falls der Gegenstand aus jedem Anspruch dieser Anmeldung nicht in einer früheren amerikanischen Patentanmeldung laut dem ersten Paragraphen des Absatzes 35 der Zivilprozeßordnung der Vereinigten Staaten, Paragraph 122 offenbart ist, erkenne ich gemäss Absatz 37, Bundesgesetzbuch, Paragraph 1.56(a) meine Pflicht zur Offenbarung von Informationen an, die zwischen dem Anmeldedatum der früheren Anmeldung und dem nationalen oder PCT internationalen Anmeldedatum dieser Anmeldung bekannt geworden sind.

I hereby claim the benefit under Title 35. United States Code. §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §122, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occured between the filing date of the prior application and the national or PCT international filing date of this application.

PCT/DE00/01276	25.04.2000		pending
(Application Serial No.) (Anmeldeseriennummer)	(Filing Date D, M, Y) (Anmeldedatum T, M, J)	(Status) (patentiert, anhängig, aufgegeben)	(Status) (patented, pending, abandoned)
(Application Serial No) (Anmeldeseriennummer)	(Filing Date D,M,Y) (Anmeldedatum T, M; J)	(Status) (patentiert, anhängig, aufgeben)	(Status) (patented, pending, abandoned)

Ich erkläre hiermit, dass alle von mir in der vorliegenden Erklärung gemachten Angaben nach meinem besten Wissen und Gewissen der vollen Wahrheit entsprechen, und dass ich diese eidesstattliche Erklärung in Kenntnis dessen abgebe, dass wissentlich und vorsätzlich falsche Angaben gemäss Paragraph 1001, Absatz 18 der Zivilprozessordnung der Vereinigten Staaten von Amerika mit Geldstrafe belegt und/oder Gefängnis bestraft werden koennen, und dass derartig wissentlich und vorsätzlich falsche Angaben die Gültigkeit der vorliegenden Patentanmeldung oder eines darauf erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

German Language Declaration

VERTRETUNGSVOLLMACHT: Als benannter Erfinder beauftrage ich hiermit den nachstehend benannten Patentanwalt (oder die nachstehend benannten Patentanwälte) und/oder Patent-Agenten mit der Verfolgung der vorliegenden Patentanmeldung sowie mit der Abwicklung aller damit verbundenen Geschäfte vor dem Patent- und Warenzeichenamt: *(Name und Registrationsnummer anführen)*

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(list name and registration number)*

And I hereby appoint

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Voller Name des einzigen oder ursprünglichen Erfinders: Dr. Thomas von der Haar	Full name of sole or first inventor: Dr. Thomas von der Haar
Unterschrift des Erfinders / Datum	Inventor's signature / Date: Thomas von der Haar 09-28-01
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Postanschrift: Schüsselwiesenweg 56	Post Office Address: Schüsselwiesenweg 56
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Voller Name des zweiten Miterfinders (falls zutreffend):	Full name of second joint inventor, if any:
Unterschrift des Erfinders / Datum	Second Inventor's signature / Date
Wohnsitz: ,	Residence: ,
Staatsangehörigkeit	Citizenship
Postanschrift	Post Office Address

(Bitte entsprechende Informationen und Unterschriften im Falle von dritten und weiteren Miterfindern angeben).

(Supply similar information and signature for third and subsequent joint inventors).